Virginia DEQ Mercury Study – Overview & Findings to Date

Virginia Mercury Symposium
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Presented by
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ICF International, San Rafael, CA

Today's Presentation

- Overview of the Virginia DEQ mercury deposition modeling study
- Background & objectives
- Key findings from literature review
- Mercury emissions inventory review
- Conceptual model of mercury deposition for VA
- Overview of the air deposition modeling analysis
- Modeling results to date
- Plans for additional modeling

VDEQ Mercury Study: Emissions Analysis & Deposition Modeling

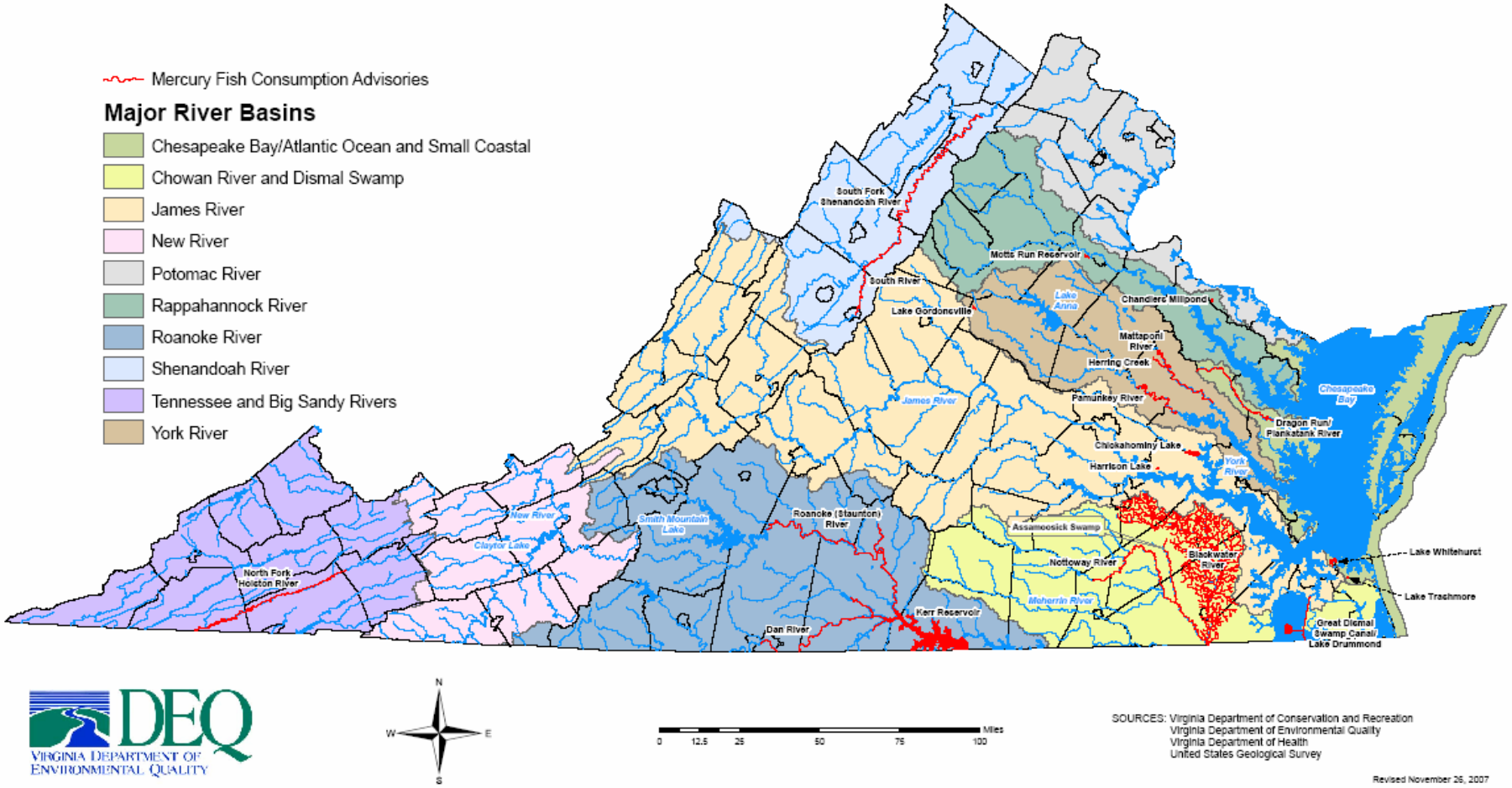
- Part A: Emissions Data Analysis (completed)
  - Review/update of VDEQ mercury emissions inventory
  - Review of recent literature on mercury emissions & deposition modeling
- Part B: Mercury Deposition Modeling (ongoing)
  - Analysis of meteorological & mercury deposition data
  - Regional-scale air quality/deposition modeling (& source contribution analysis)
  - Local-scale (single-source) air quality/deposition modeling
  - Future-year emissions projections & modeling

Background

- Atmospheric deposition of mercury is a source of mercury contamination in surface waters
- In the U.S., more than 8,500 bodies of water have been identified as mercury impaired
- Within Virginia, fish consumption advisories have been issued for several bodies of water
  - located primarily along the coastal plain
  - susceptible to mercury methylation & bioaccumulation

- HB1055 requires analysis of the sources of mercury & assessment of future-year controls

Waters Under VDH Fish Consumption Advisories For Mercury



DEQ
Virginia Department of Environmental Quality

SOURCES: Virginia Department of Conservation and Recreation
Virginia Department of Environmental Quality
Virginia Department of Health
United States Geological Survey

Revised November 26, 2007

Virginia Fish Consumption Advisories: Rivers

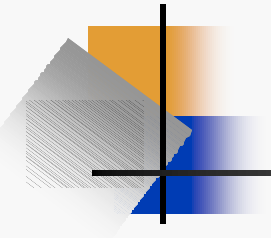
- North Fork Holston
- Roanoke (Staunton)
- Dan
- South Fork Shenandoah
- Herring Creek/Mattaponi
- Pamunkey
- Nottoway
- Blackwater
- Dragon Run/Piankatank

Virginia Fish Consumption Advisories: Other Waterbodies

- Kerr Reservoir
- Lake Gordonsville
- Motts Run Reservoir
- Chandlers Millpond
- Chickahominy Lake
- Harrison Lake
- Assamoosick Swamp
- Lake Whitehurst
- Lake Trashmore
- Great Dismal Swamp Canal/Lake Drummond

Virginia Mercury Study Objectives

- Review & update the Virginia mercury point source emission inventory
- Analyze historical data & prepare a “conceptual description” of mercury deposition characteristics
- Conduct air quality modeling to simulate & quantify the contribution of global, regional & local emissions
- Evaluate the effectiveness of future national & state control measures to meet water quality goals



Literature Review

Literature Review

- Literature review focused on recent (2000-2007) work covering:
  - General/state-specific studies
  - Mercury emissions & controls
  - Mercury concentration & deposition measurement studies
  - Mercury deposition modeling techniques
- More than 85 documents compiled & reviewed

Key Findings from Literature Review: Sources of Mercury

- Mercury is emitted to the atmosphere from both natural & anthropogenic sources
- Three forms of airborne mercury are: elemental mercury (HG0), reactive gaseous mercury (RGM or HG2) & particulate mercury (HGP)
- HG0 has a long atmospheric lifetime & is dispersed & transported globally by atmospheric circulation systems
- RGM & HGP have shorter atmospheric lifetimes & are subject to regional-scale transport

Key Findings from Literature Review: Deposition & Re-emission

- Atmospheric deposition from global, regional & local sources is a primary source of mercury for impaired water bodies
- Most measurements are for wet mercury deposition, but studies have found that dry deposition is also important
- Spatial patterns in the wet deposition data are correlated with rainfall patterns & suggest impacts from regional & local sources
- Re-emission of mercury complicates the analysis of mercury deposition & is an active area of research

Key Findings from Literature Review: Deposition Modeling

- Areas of uncertainty in mercury deposition modeling include:
  - Quantifying global emissions
  - Natural emission & re-emission of mercury
  - Input meteorology (especially rainfall)
  - Rates of chemical reactions
  - Dispersion & chemistry of plumes
  - Deposition of elemental mercury

Key Findings from Literature Review: Emissions Controls

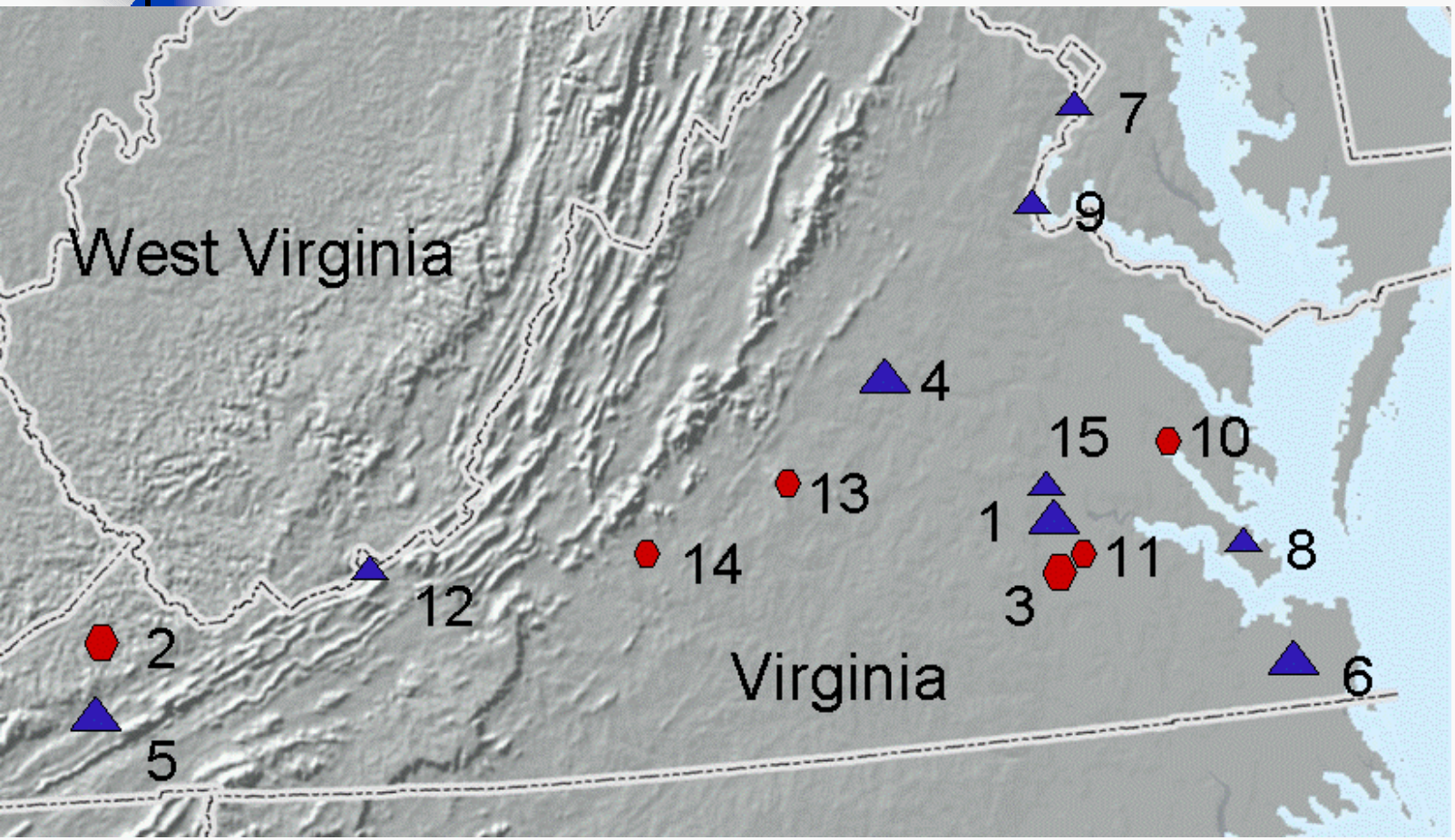
- Various tests have found selective catalytic reduction (SCR) to be effective in reducing mercury emissions from coal-fired power plants
  - Effectiveness of SCR depends on type of coal
  - Other techniques may enhance mercury removal
- State agencies including NC (2005), MN (2005) & NESCAUM (2004) have evaluated potential mercury control technologies
- MN found changes in “product use and disposal” (e.g. for paint, electric switches, batteries) have reduced mercury air emissions

Mercury Emissions Inventory Review

Mercury Emissions Inventory Review Tasks

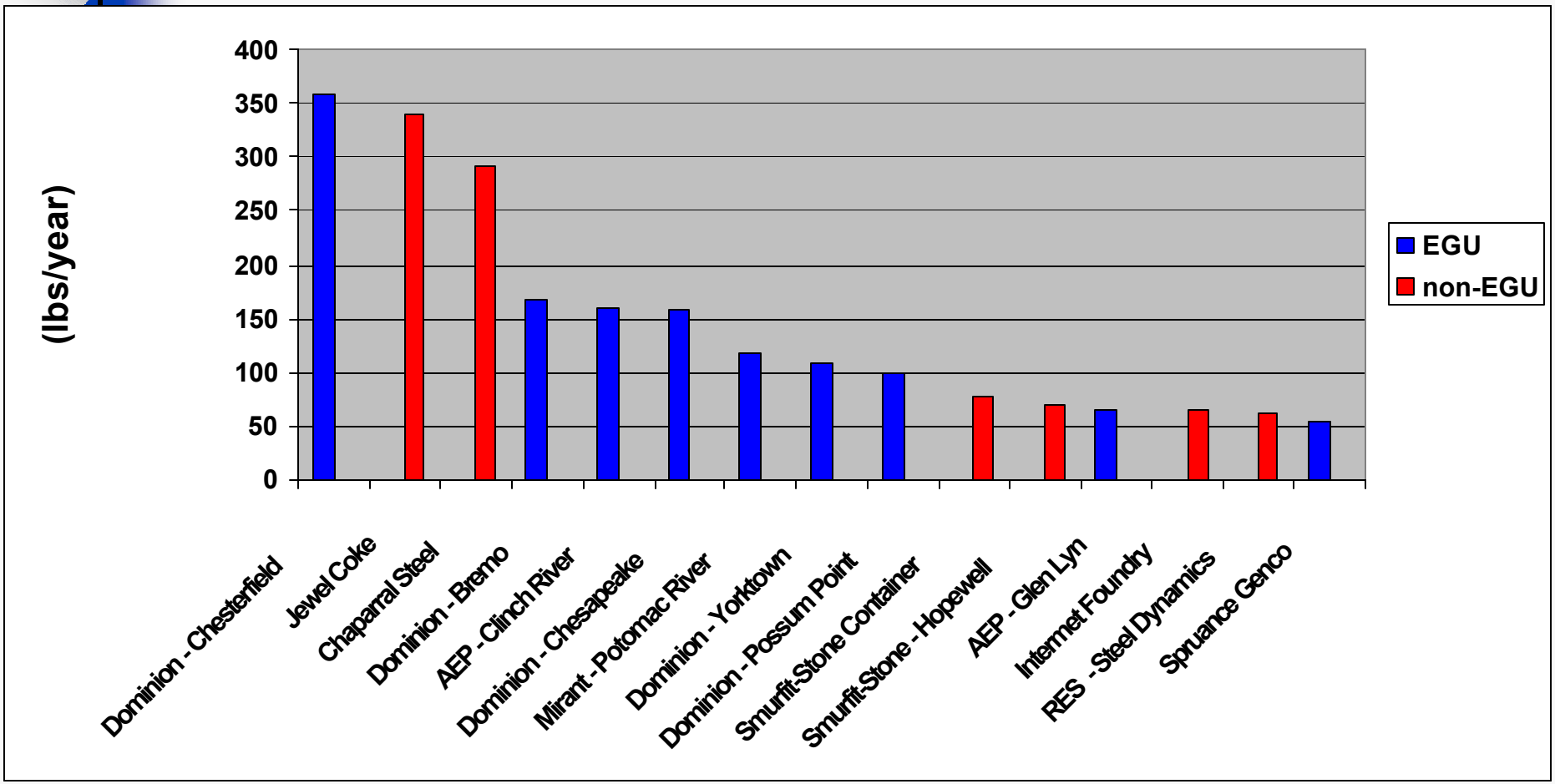
- Reviewed & QA'd updated VA mercury emissions data obtained by VDEQ survey
  - 2002 & 2005 emissions
  - 70 point sources
- Obtained & reviewed latest (2002) EPA national mercury inventory (NEI, Version 3)
- Compared updated Virginia emissions inventory with NEI

15 Largest Mercury Point Sources in Virginia (2002)

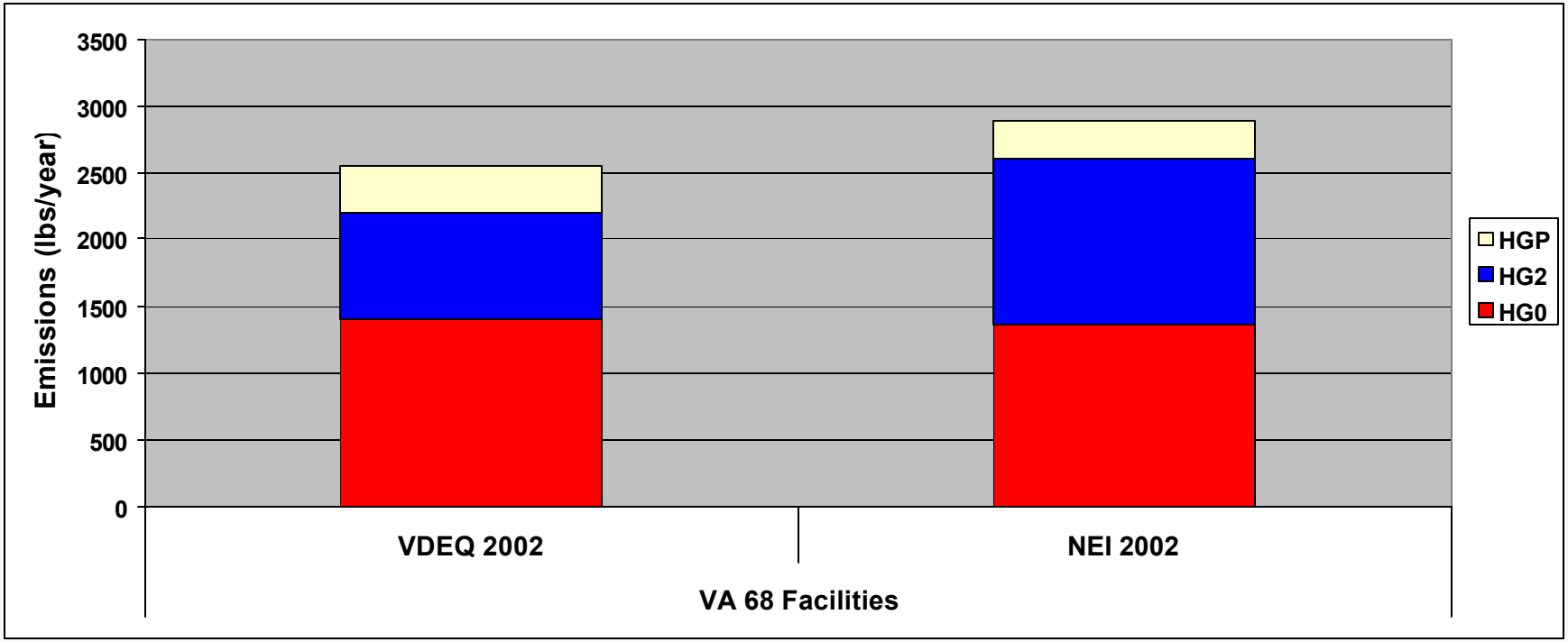


Top 15 sources comprise 86% of mercury emissions for VA

Summary of Mercury Emissions for Top 15 Point Sources in VA (2002)



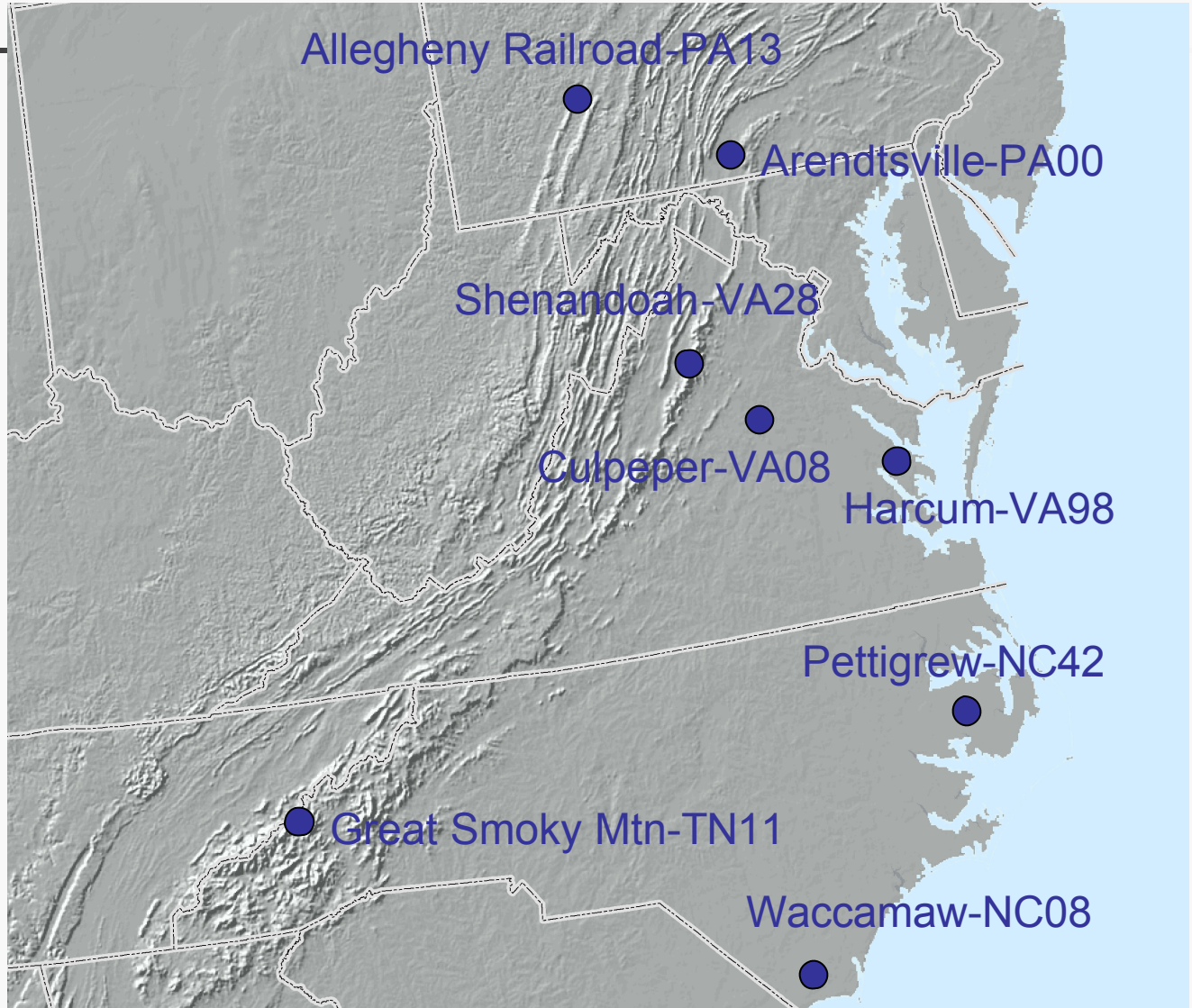
Comparison of VDEQ & NEI Emissions for Virginia (2002)



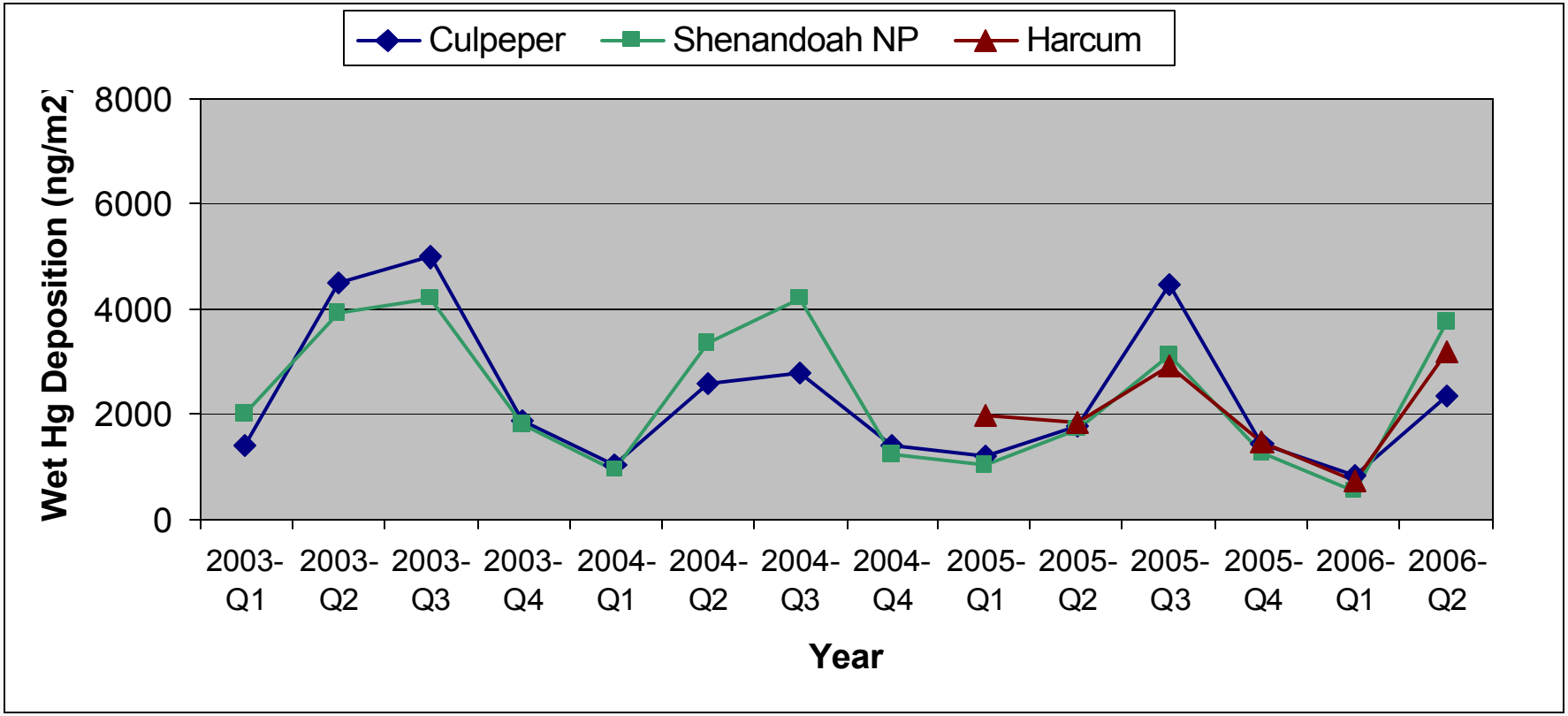
HG0 = Elemental Mercury; HG2 = Reactive Gaseous Mercury; HGP = Particulate Mercury

Conceptual Description of Mercury Deposition for Virginia

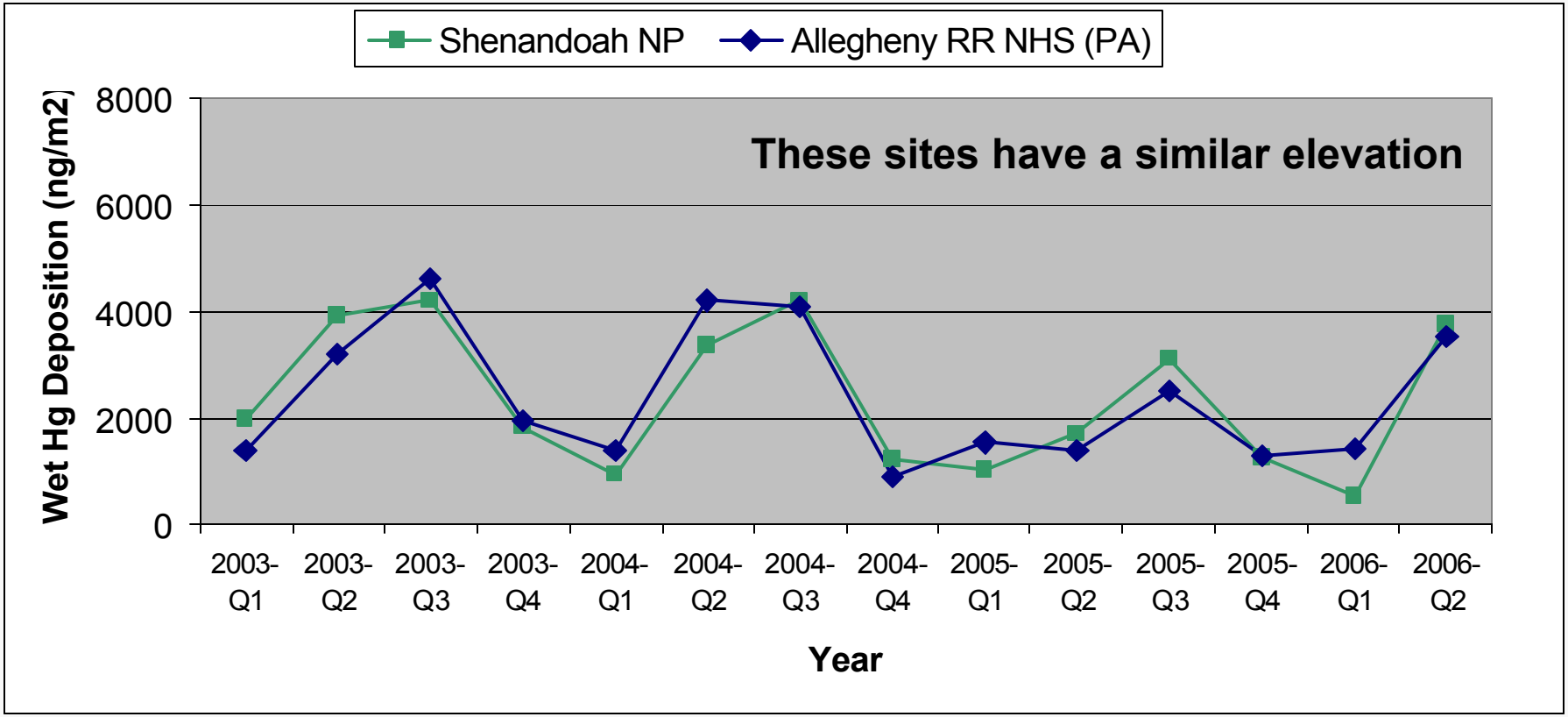
Regional Mercury Deposition Network (MDN) Monitoring Sites



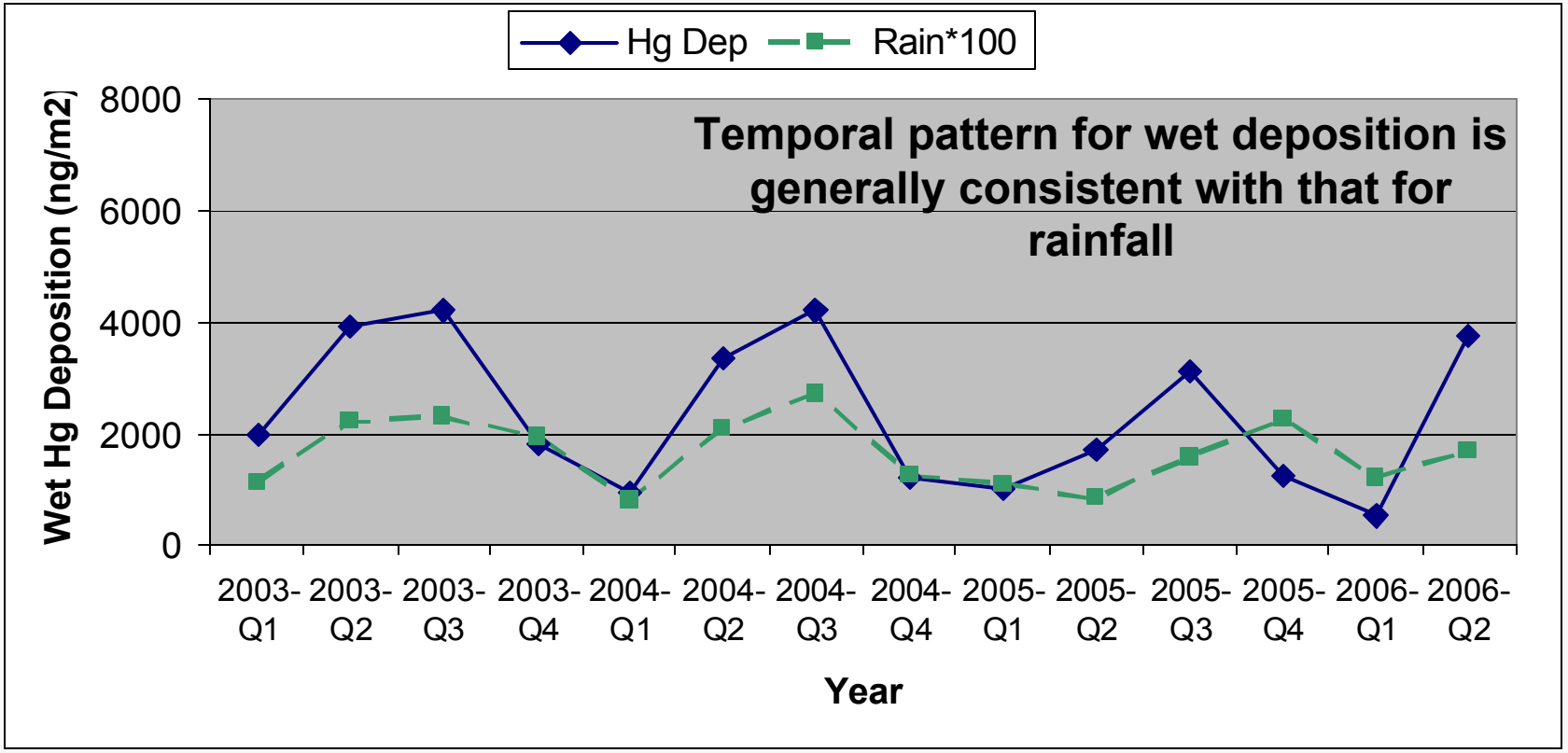
Quarterly Mercury Wet Deposition for VA MDN Sites



Quarterly Mercury Wet Deposition for Selected VA & PA MDN Sites



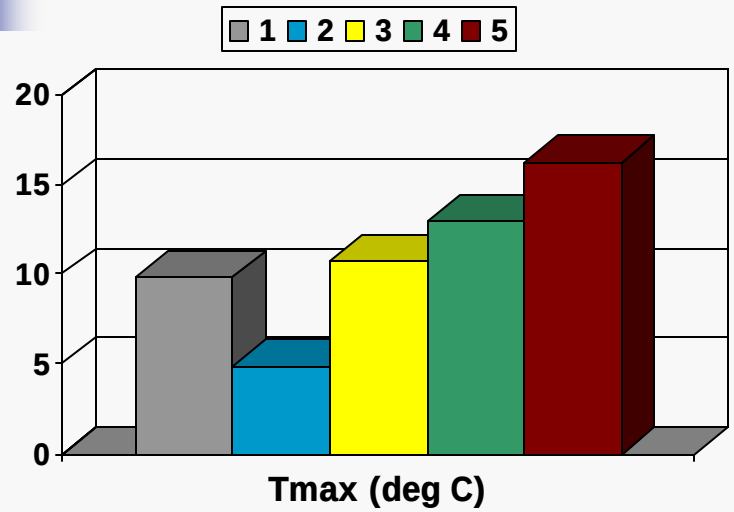
Comparison of Mercury Wet Deposition & Rainfall Amount

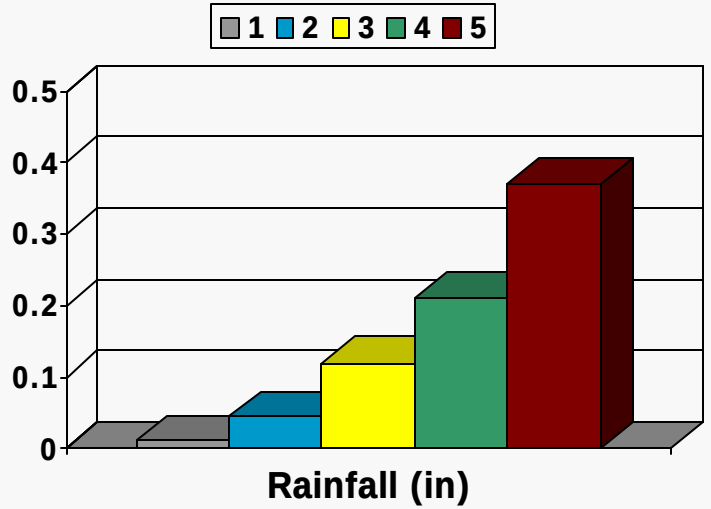


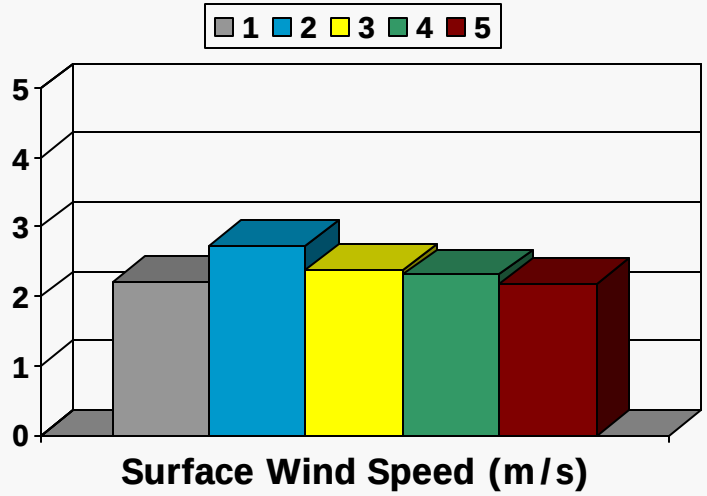
Shenandoah National Park

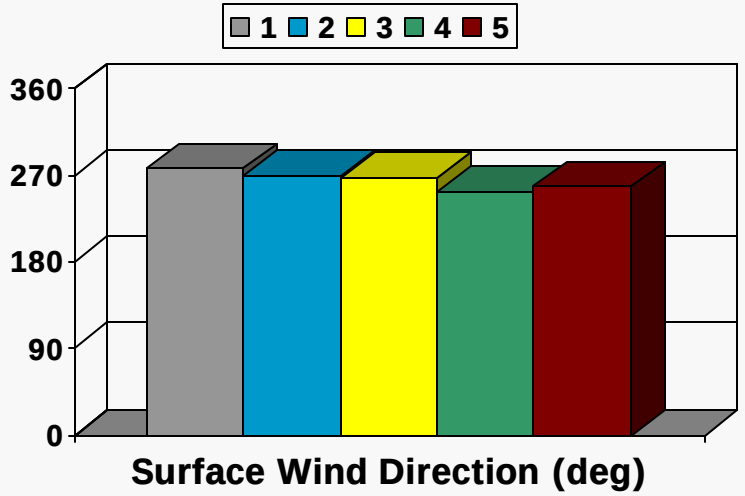
Meteorological Variations & Mercury Deposition for Shenandoah NP

Colors Represent 5 Hg Deposition Ranges (Gray = Lowest)

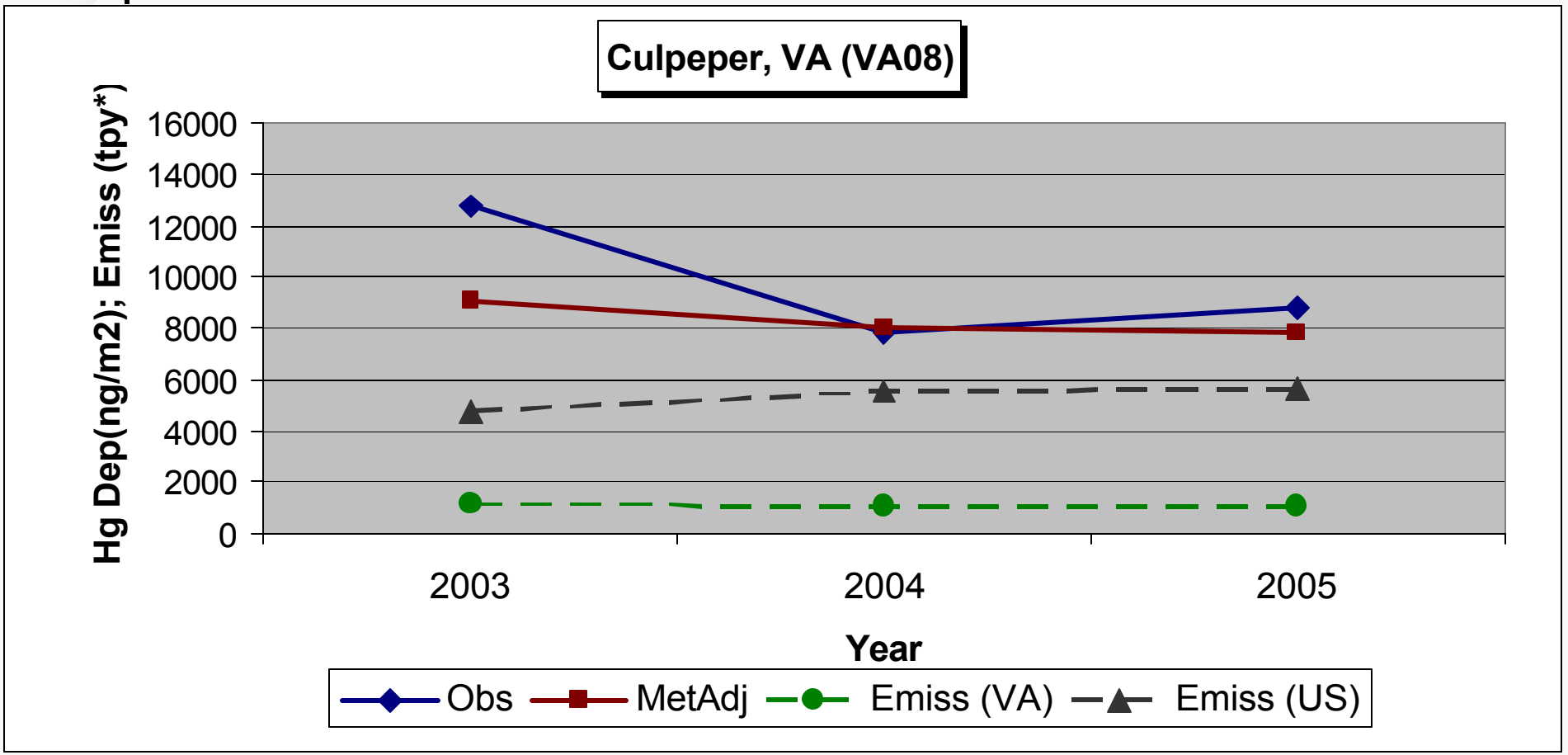






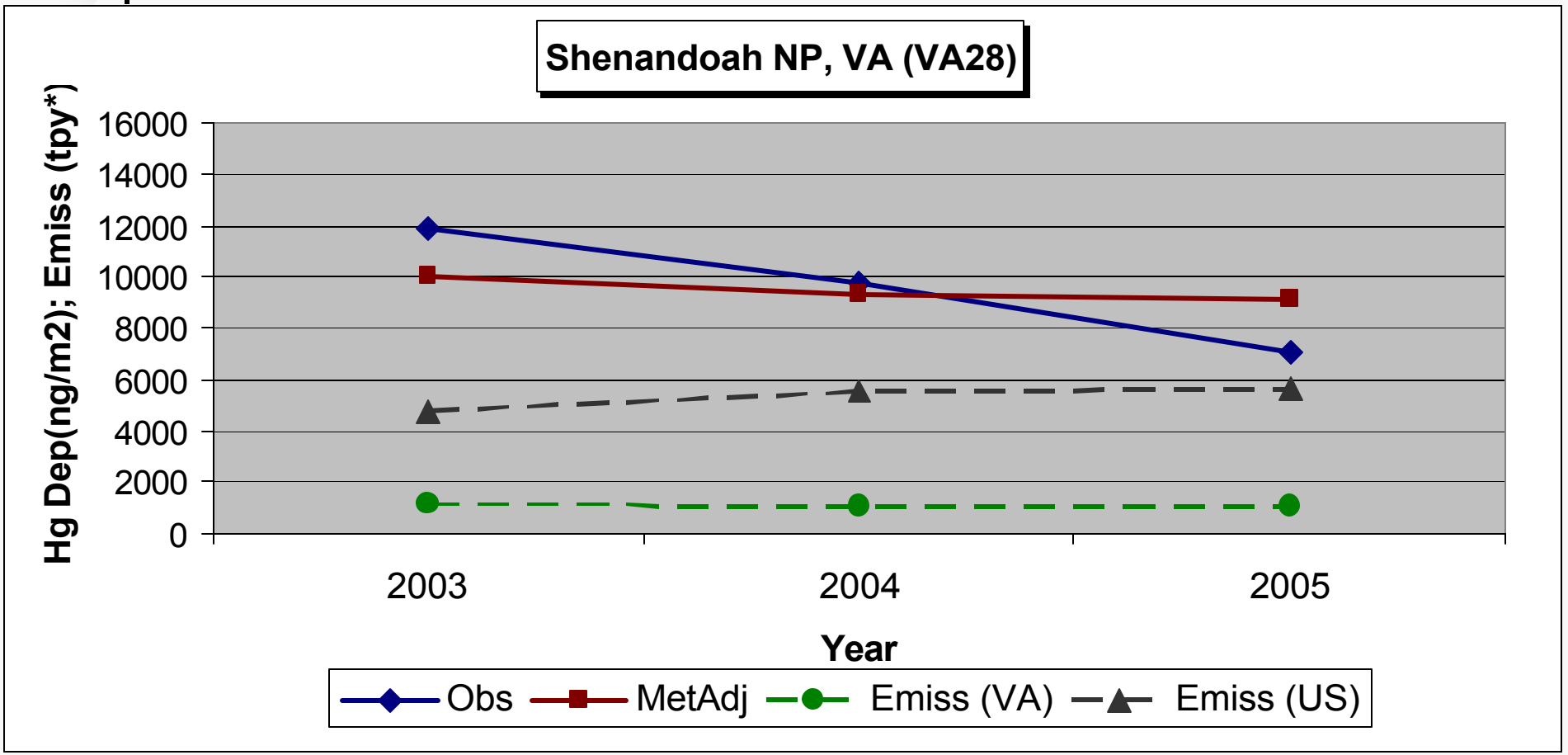


Meteorologically Adjusted "Trends" w/Emissions: Culpeper



***VA emissions are tpy x 1000; U.S. emissions are tpy x 50**

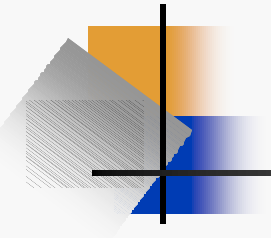
Meteorologically Adjusted "Trends" w/Emissions: Shenandoah NP



***VA emissions are tpy x 1000; U.S. emissions are tpy x 50**

A Few Highlights from the Conceptual Model

- Mercury deposition characteristics for VA sites are similar to those for geographically similar sites within the mid-Atlantic region
- Wet deposition has a seasonal component and, as expected, is correlated with rainfall
- Rainfall amount does not fully explain the variations in deposition (there are other influences)
- Mercury deposition & emissions “trends” (2003-2005) are flat with a slight downward tendency for VA sites



Air Quality Modeling of Mercury Deposition

Mercury Deposition Modeling Approach: Baseline Modeling

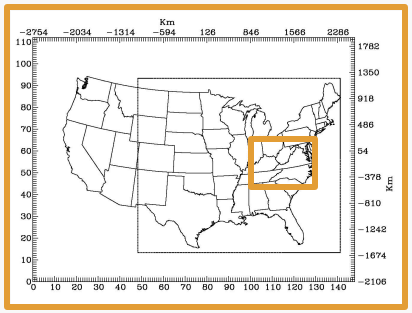
2001 Meteorological Inputs

2002 Criteria Pollutant & Mercury Emissions

Community Multiscale Air Quality (CMAQ) Model, Version 4.6

AERMOD Gaussian Model

AERMOD Sensitivity Analysis



CMAQ Sensitivity Analysis

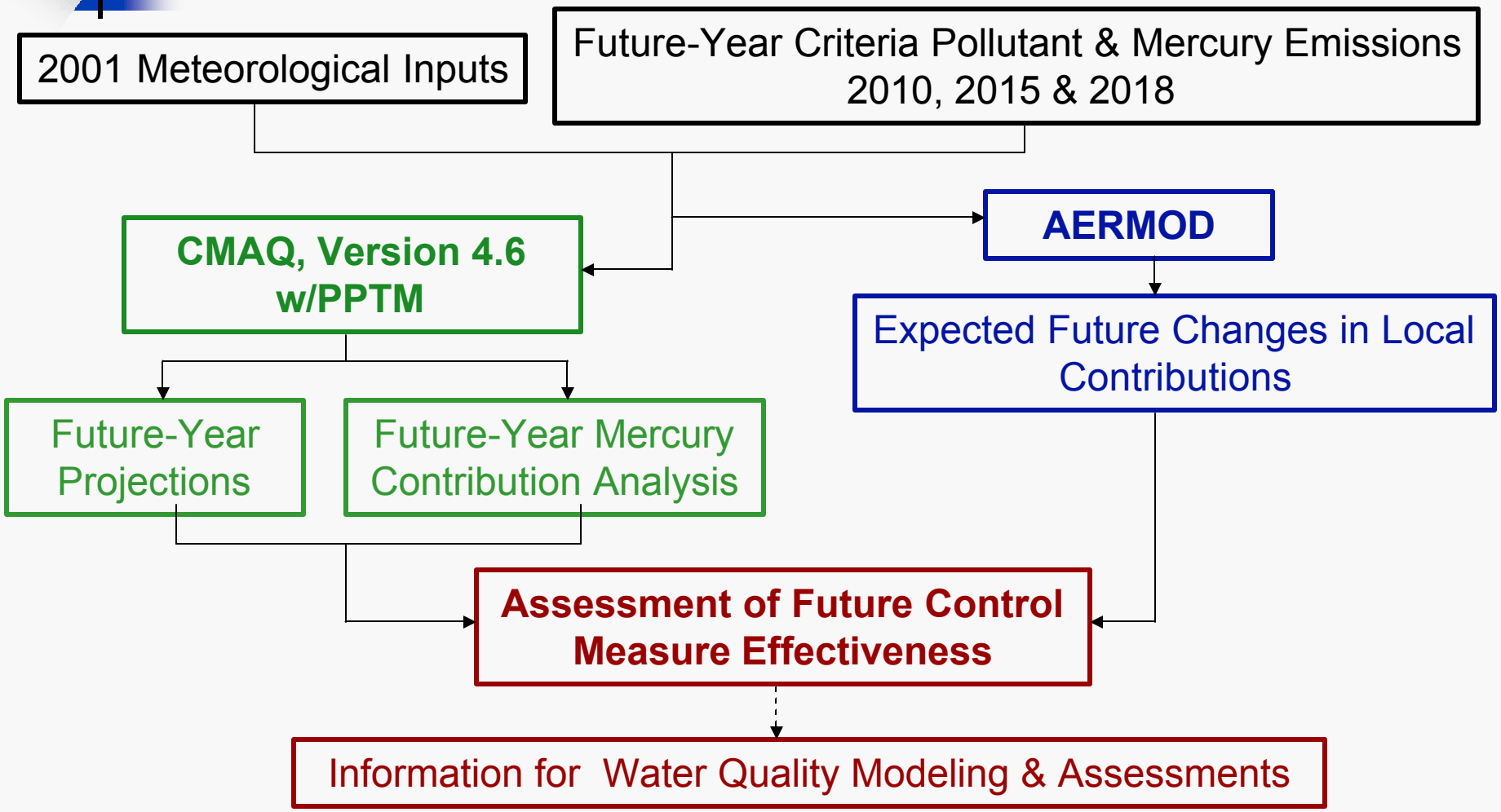
Identification of Sources with Significant Local Contributions

CMAQ Performance Evaluation

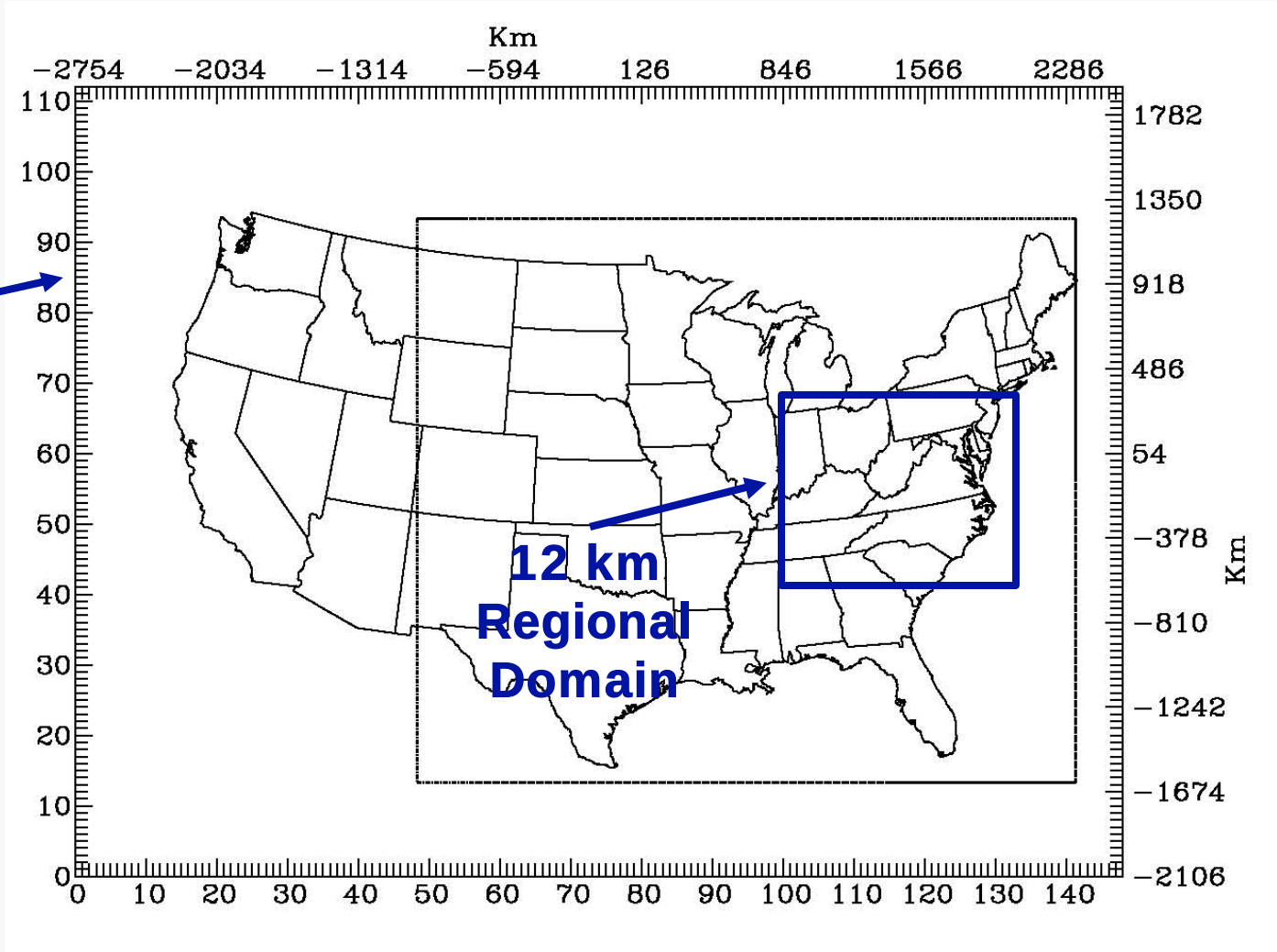
CMAQ Particle & Precursor Tagging Methodology (PPTM)

Assessment of Global, National, Regional, & Source-Specific Contributions

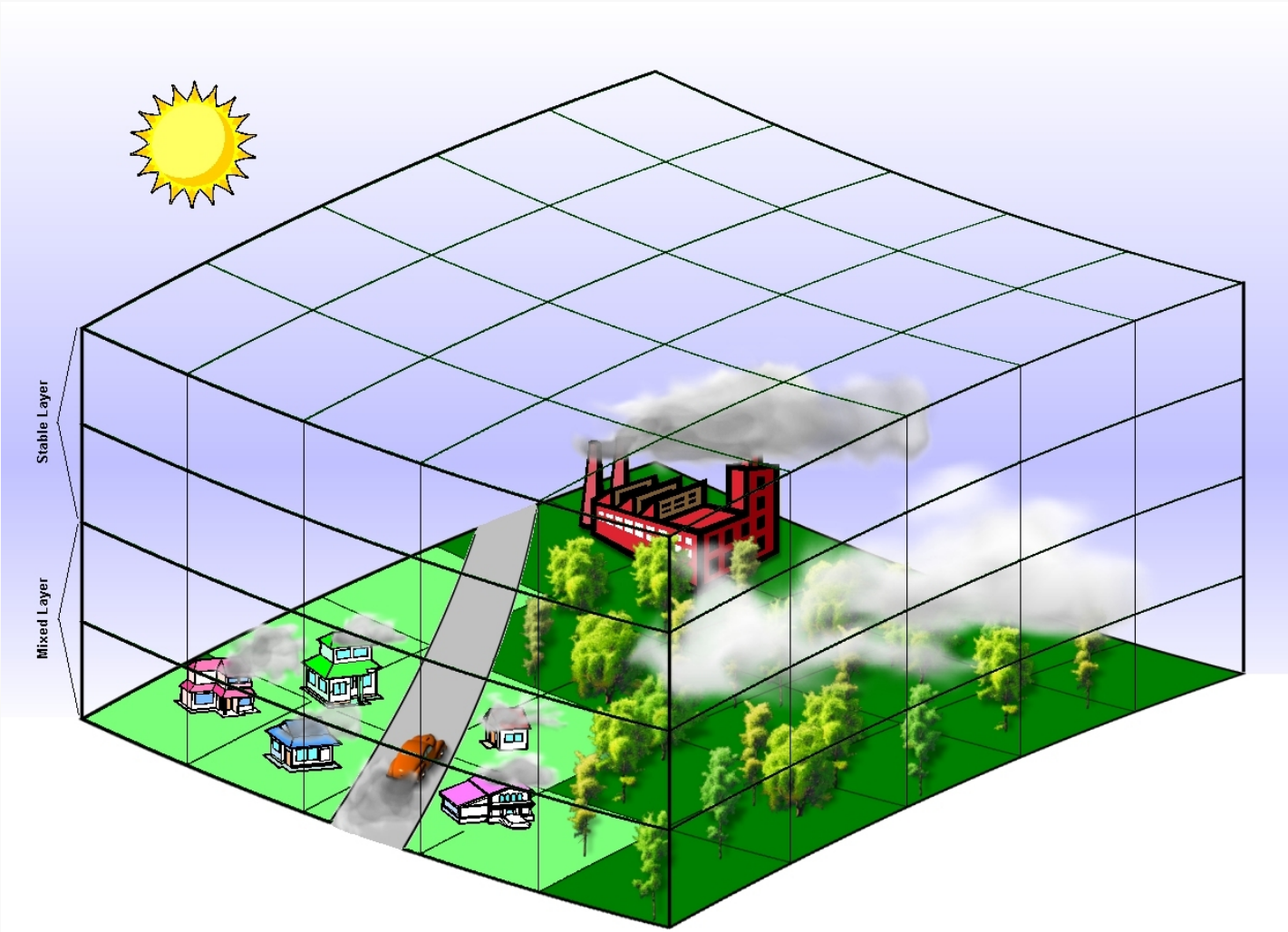
Mercury Deposition Modeling Approach: Future-Year Modeling



Virginia Mercury Study
CMAQ Modeling Domains



Grid Model Concept



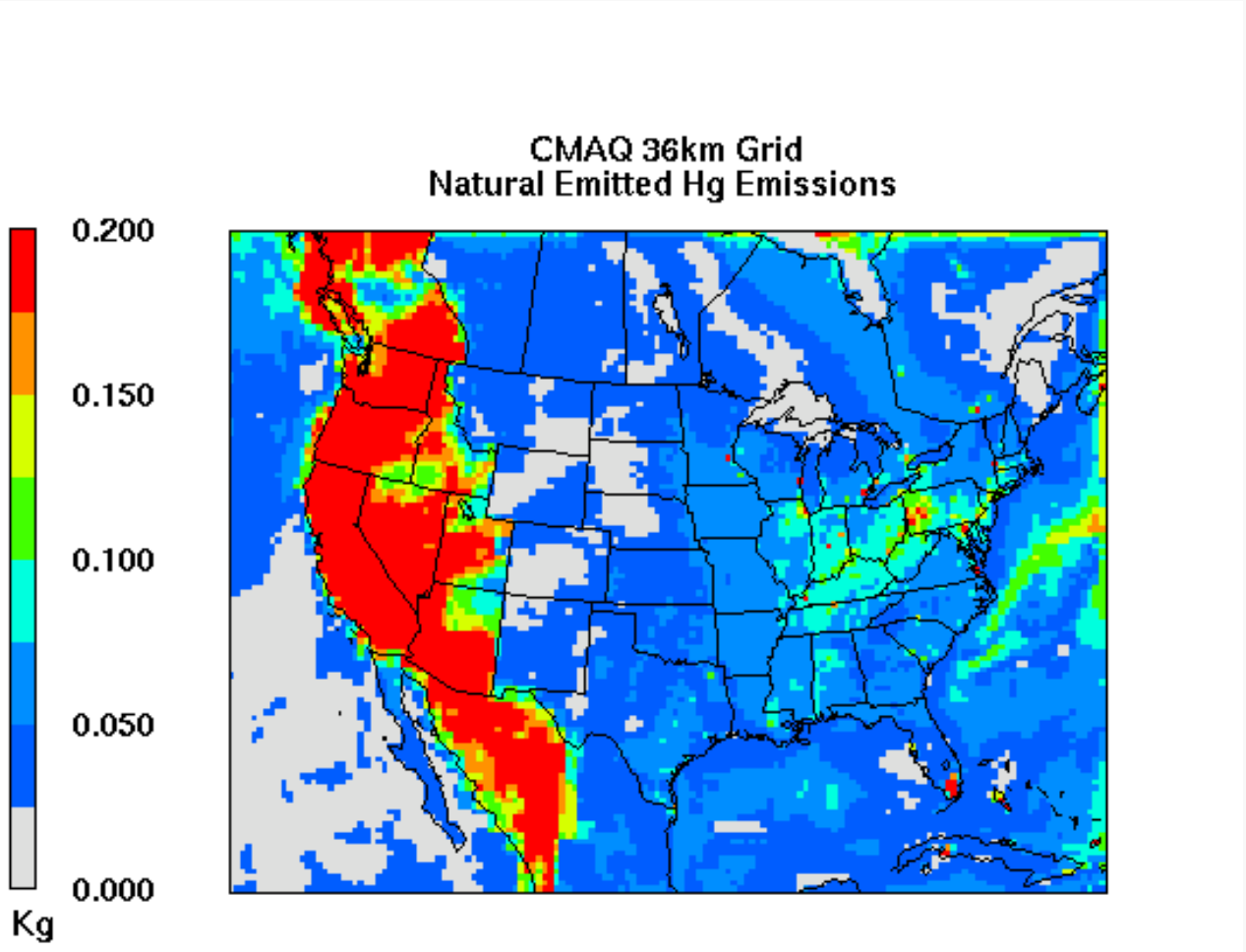
CMAQ Version 4.6 w/Mercury

- Three species: elemental mercury (HG0), reactive gaseous mercury (RGM or HG2), & particulate mercury (HGP)
- Gaseous & aqueous reactions involving mercury (Bullock & Breme, 2002)
- Recent enhancements include: improved dry deposition algorithm, natural emissions & PPTM

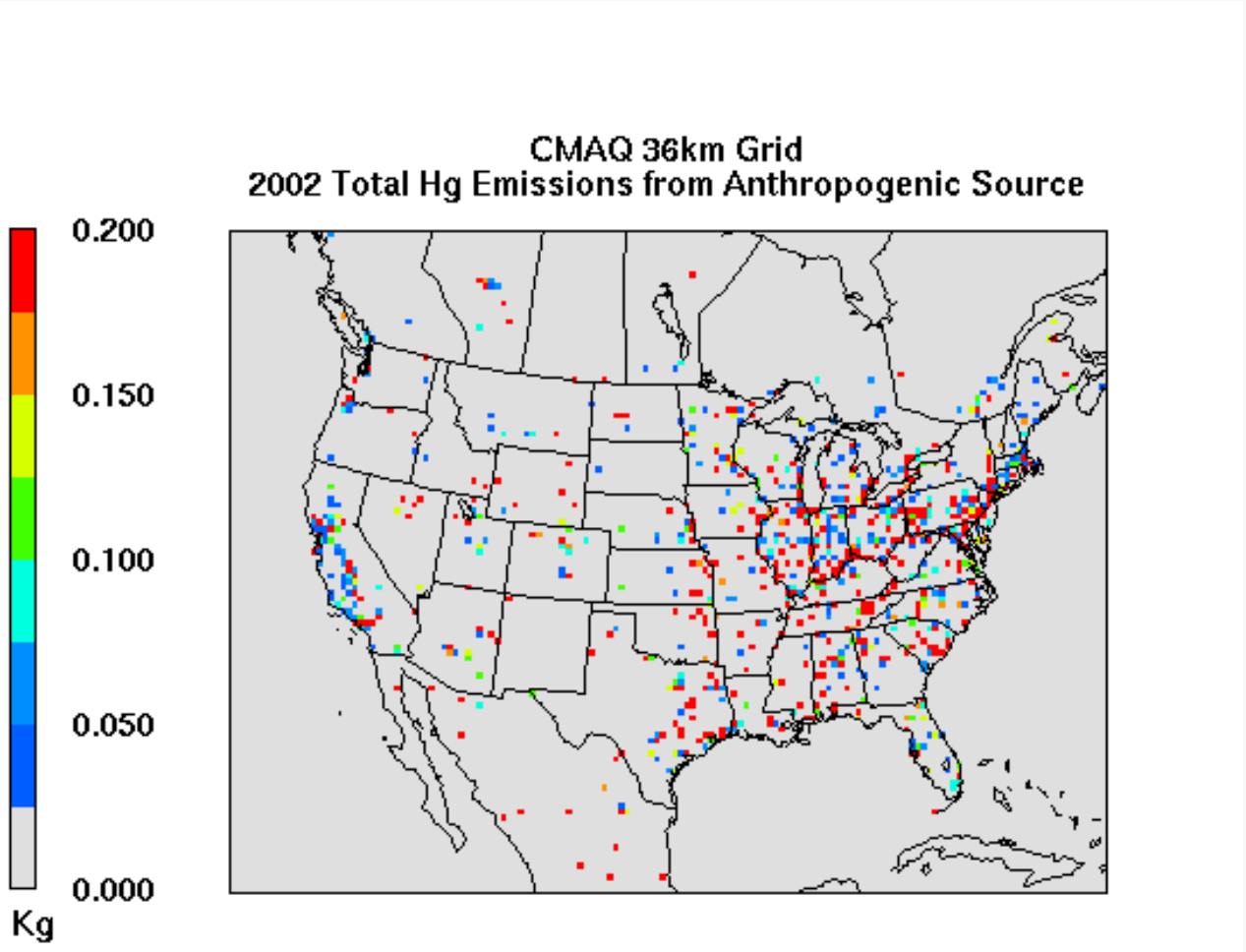
CMAQ Particle & Precursor Tagging Methodology (PPTM)

- PPTM can be applied for all PM species & for mercury
- Emissions or initial/boundary condition (IC/BC) species are tagged & continuously tracked throughout the simulation
- Emissions tags can be applied to source regions, source categories & individual sources
- PPTM quantifies the contribution of tagged sources to simulated species concentrations & deposition

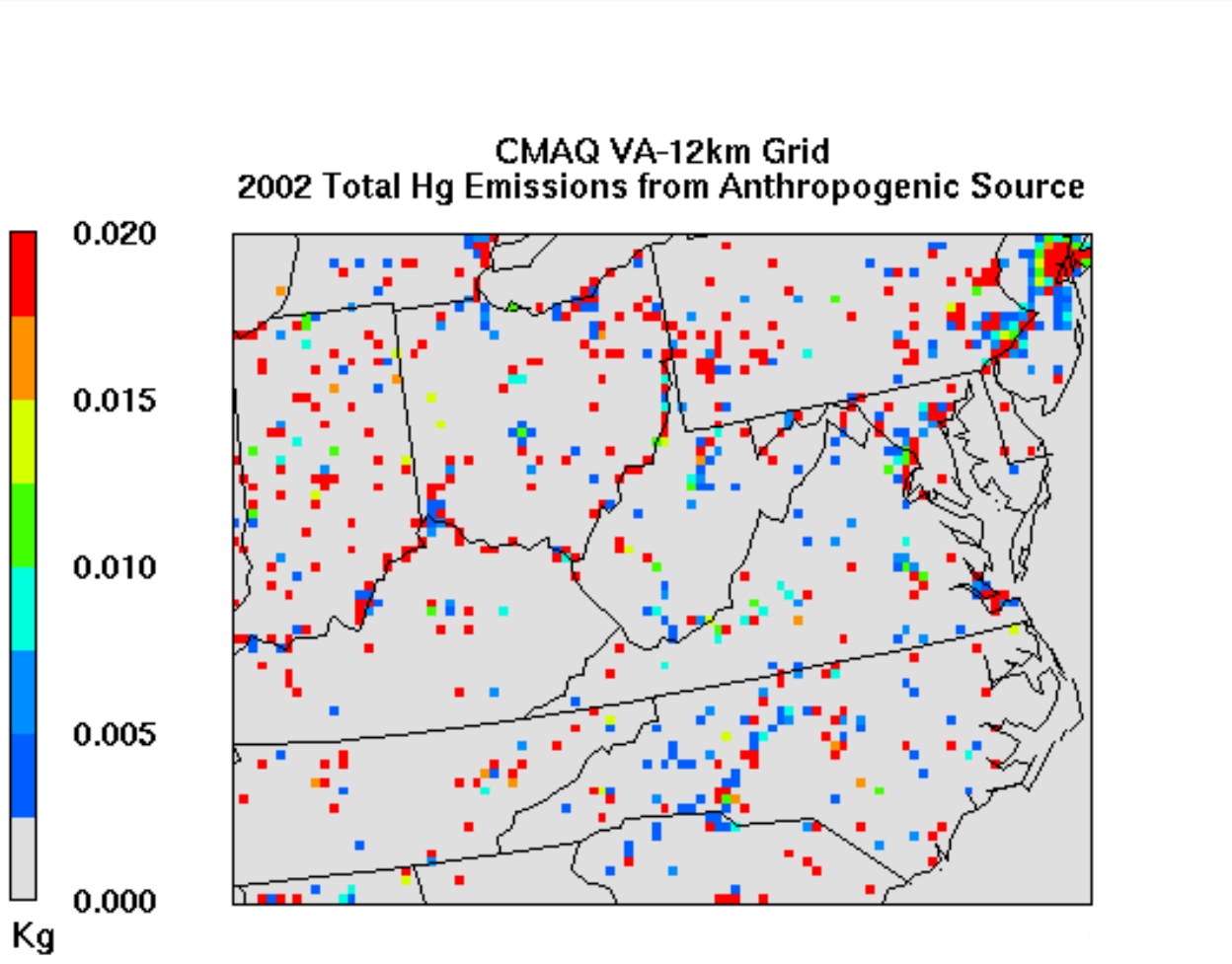
Natural Emissions of Mercury: CMAQ 36-km Modeling Domain



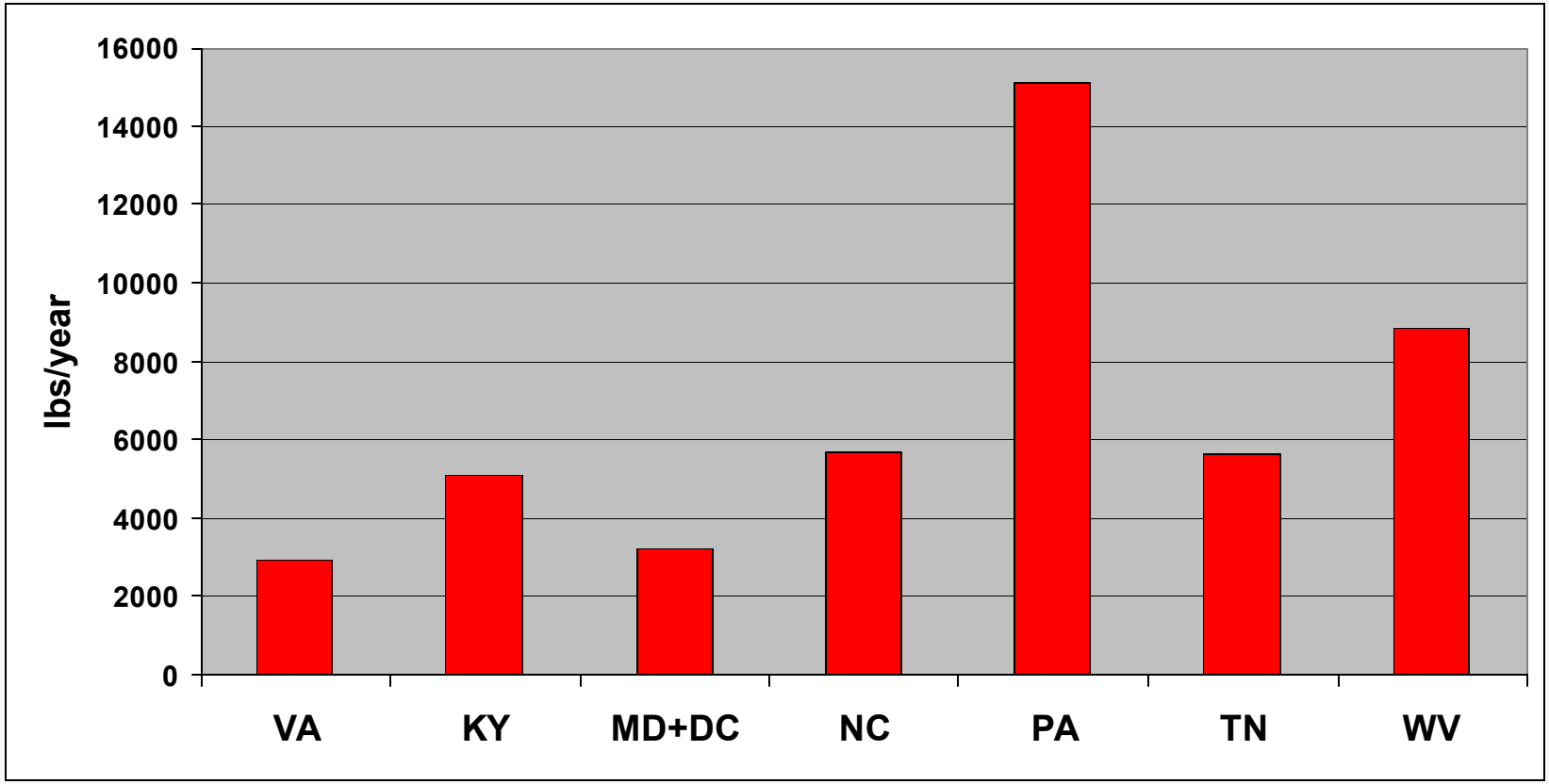
Anthropogenic Emissions of Mercury: CMAQ 36-km Modeling Domain



Anthropogenic Emissions of Mercury: CMAQ 12-km Modeling Domain

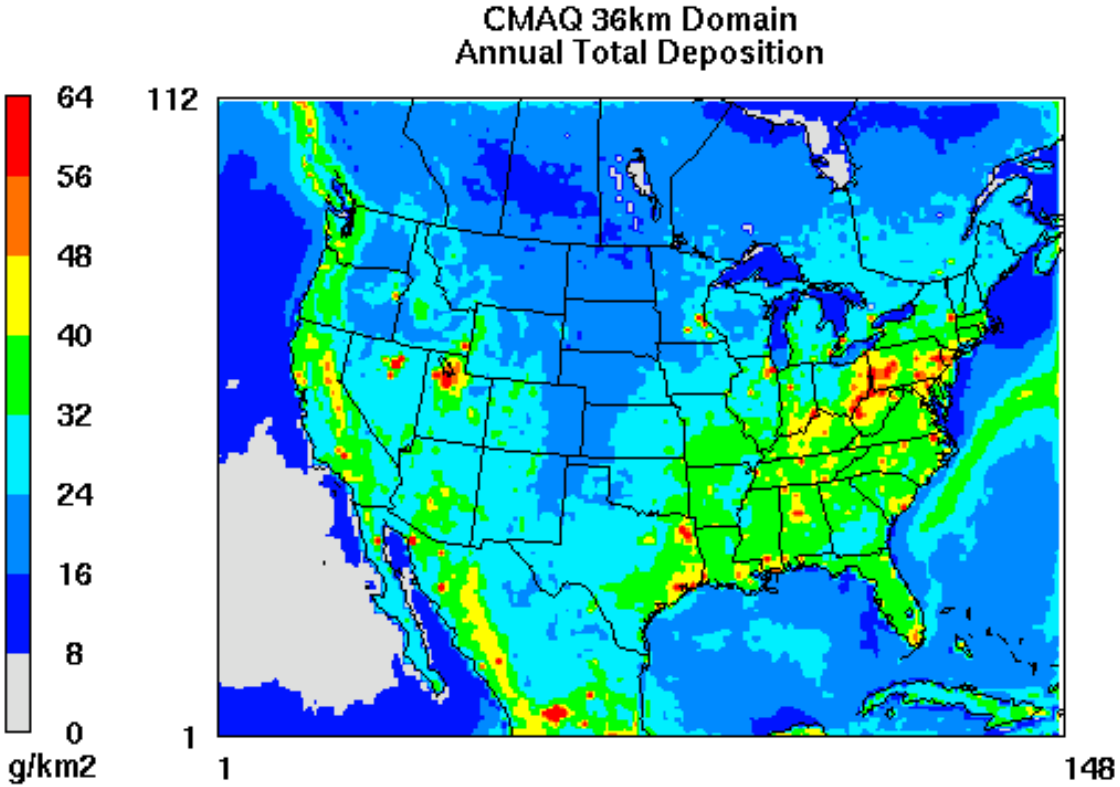


Summary of Mercury Emissions for VA & Surrounding States



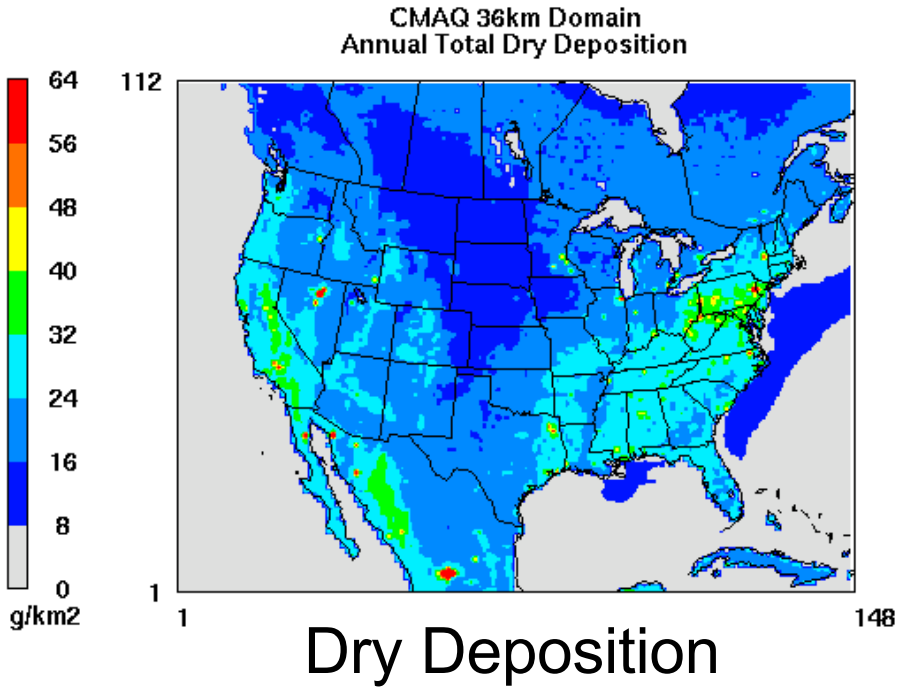
Based on 2002 VDEQ & NEI Version 3 emissions

CMAQ Annual Mercury Deposition: Initial Simulation (36-km)

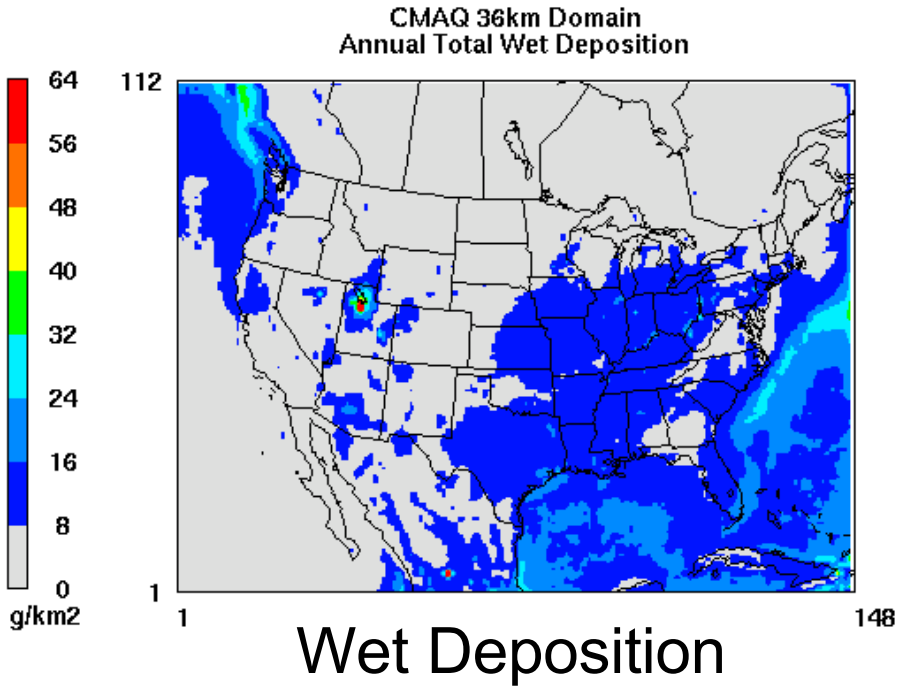


Total Mercury Deposition

CMAQ Annual Mercury Deposition: Initial Simulation (36-km)

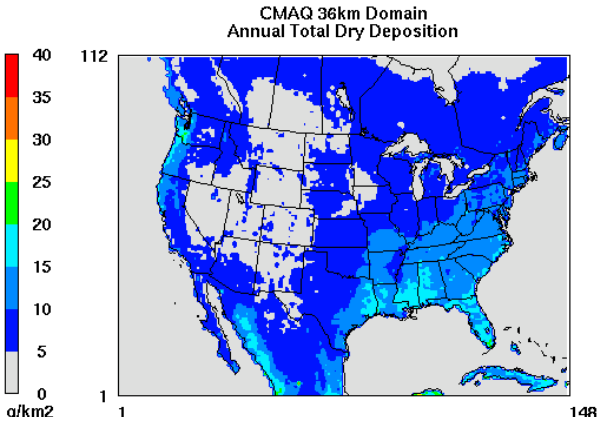


Dry Deposition

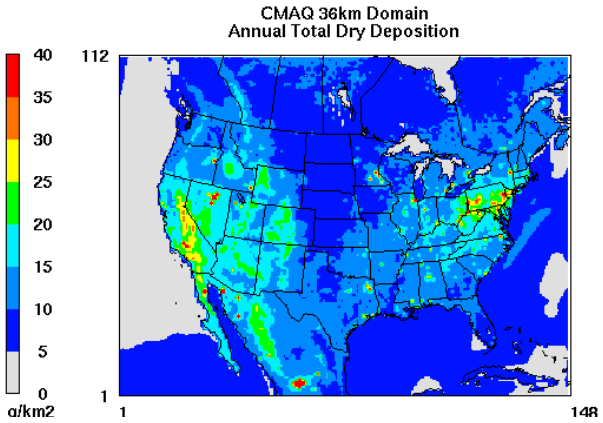


Wet Deposition

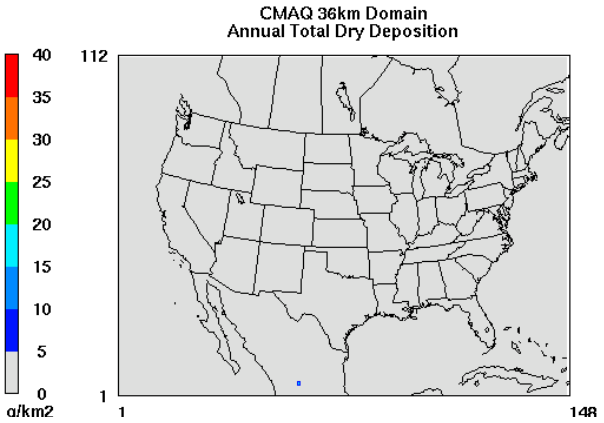
CMAQ Initial Simulation: Dry Mercury Deposition by Species



Elemental (HG0)

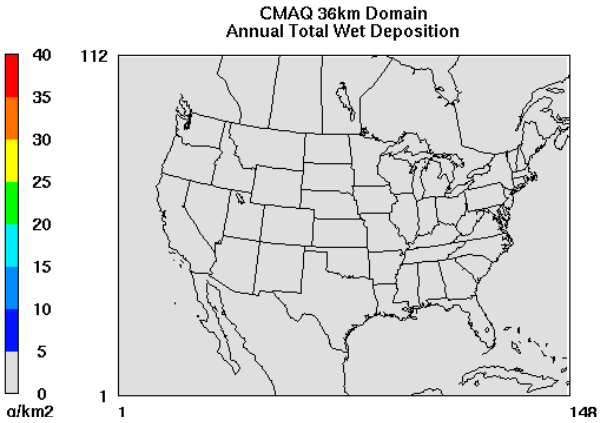


Reactive Gaseous (HG2)

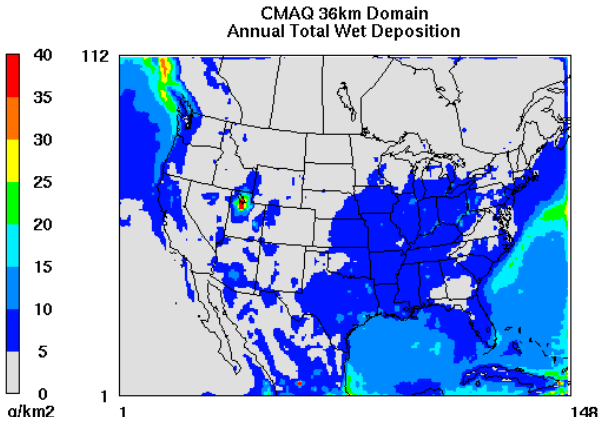


Particulate (HGP)

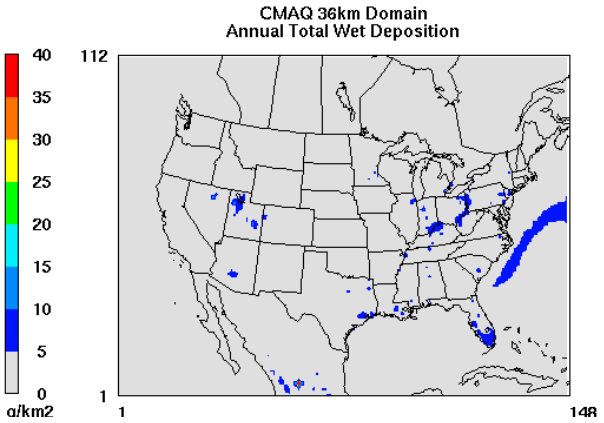
CMAQ Initial Simulation: Wet Mercury Deposition by Species



Elemental (HG0)

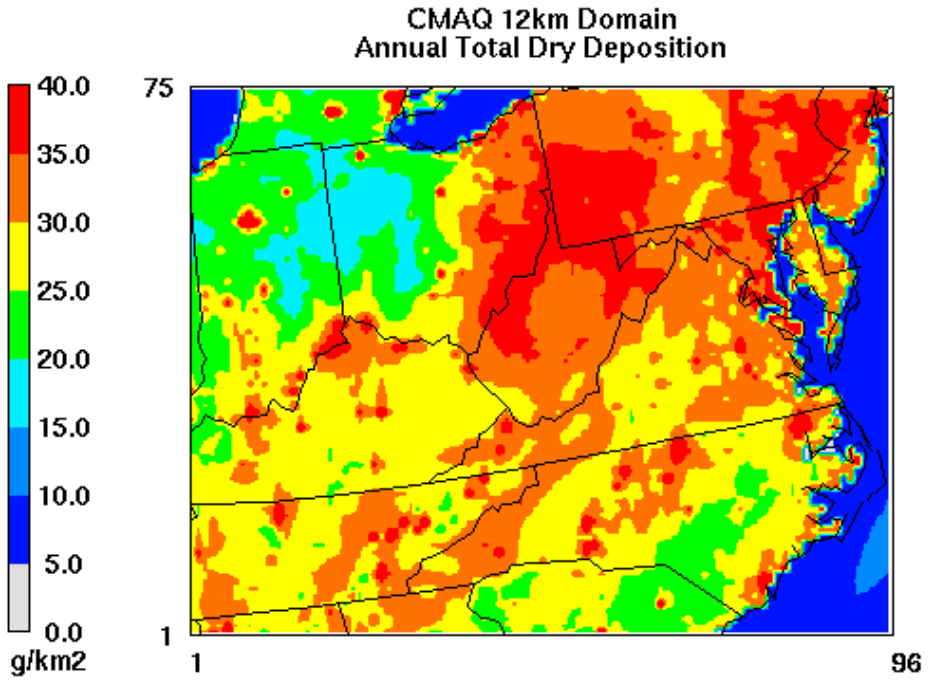


Reactive Gaseous (HG2)

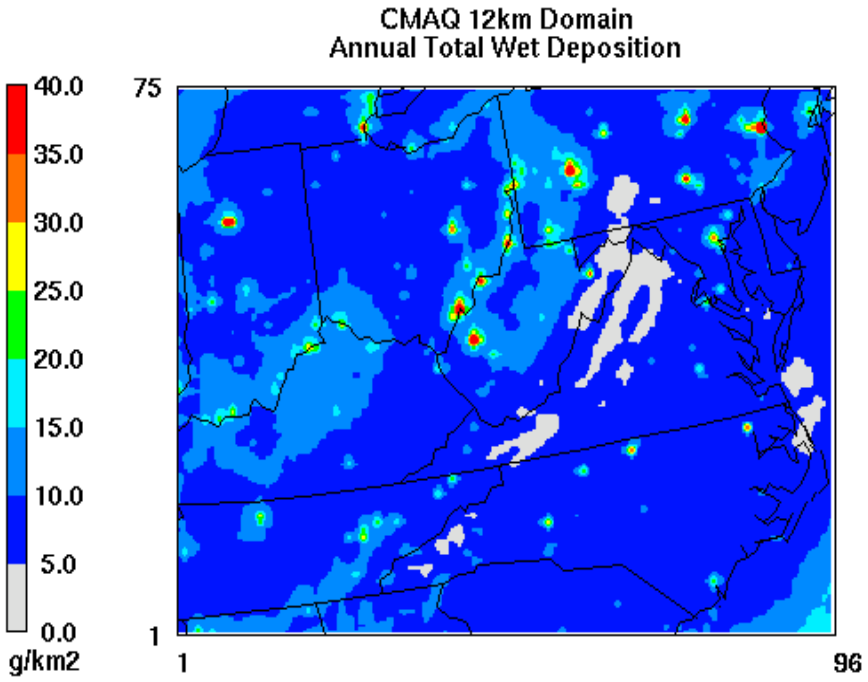


Particulate (HGP)

CMAQ Annual Mercury Deposition: Initial Simulation (12-km)

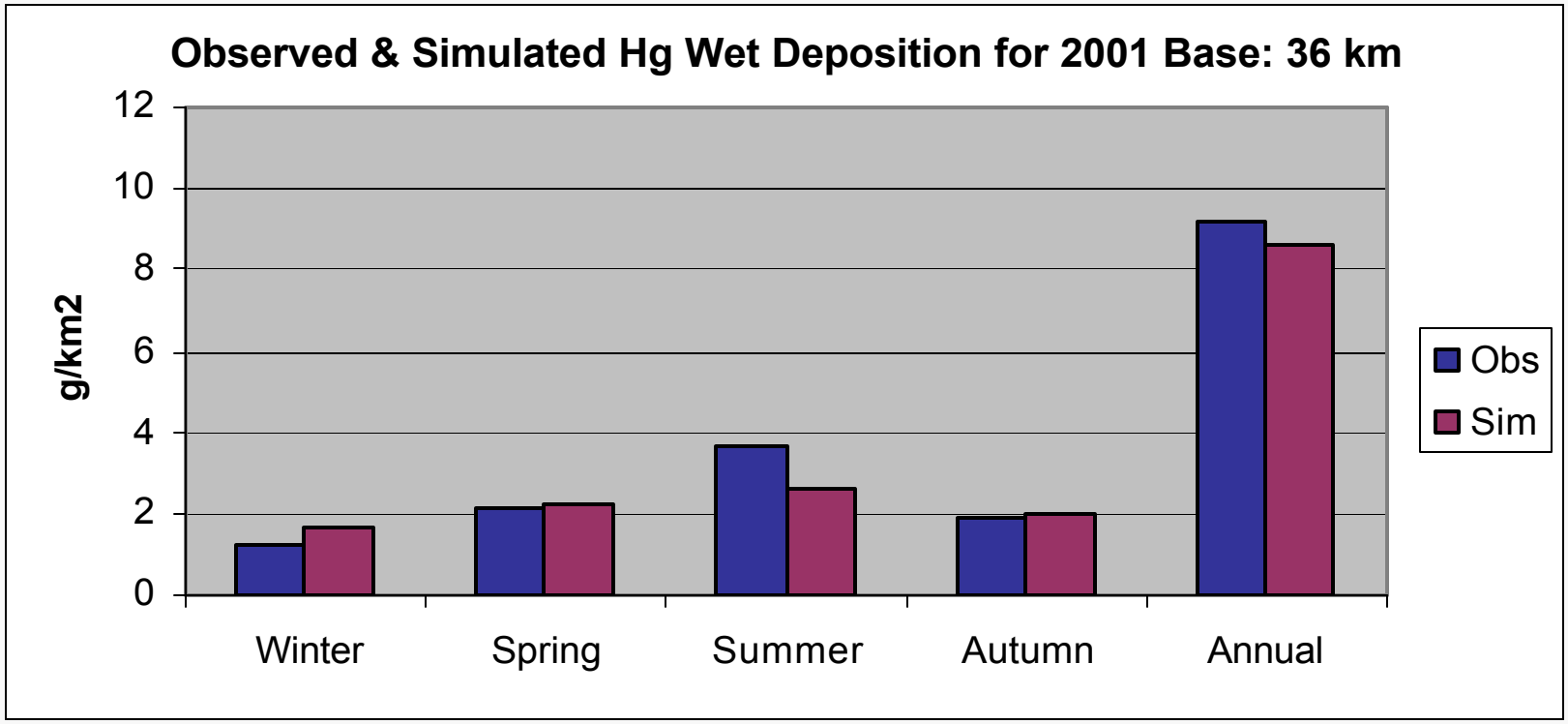


Dry Deposition



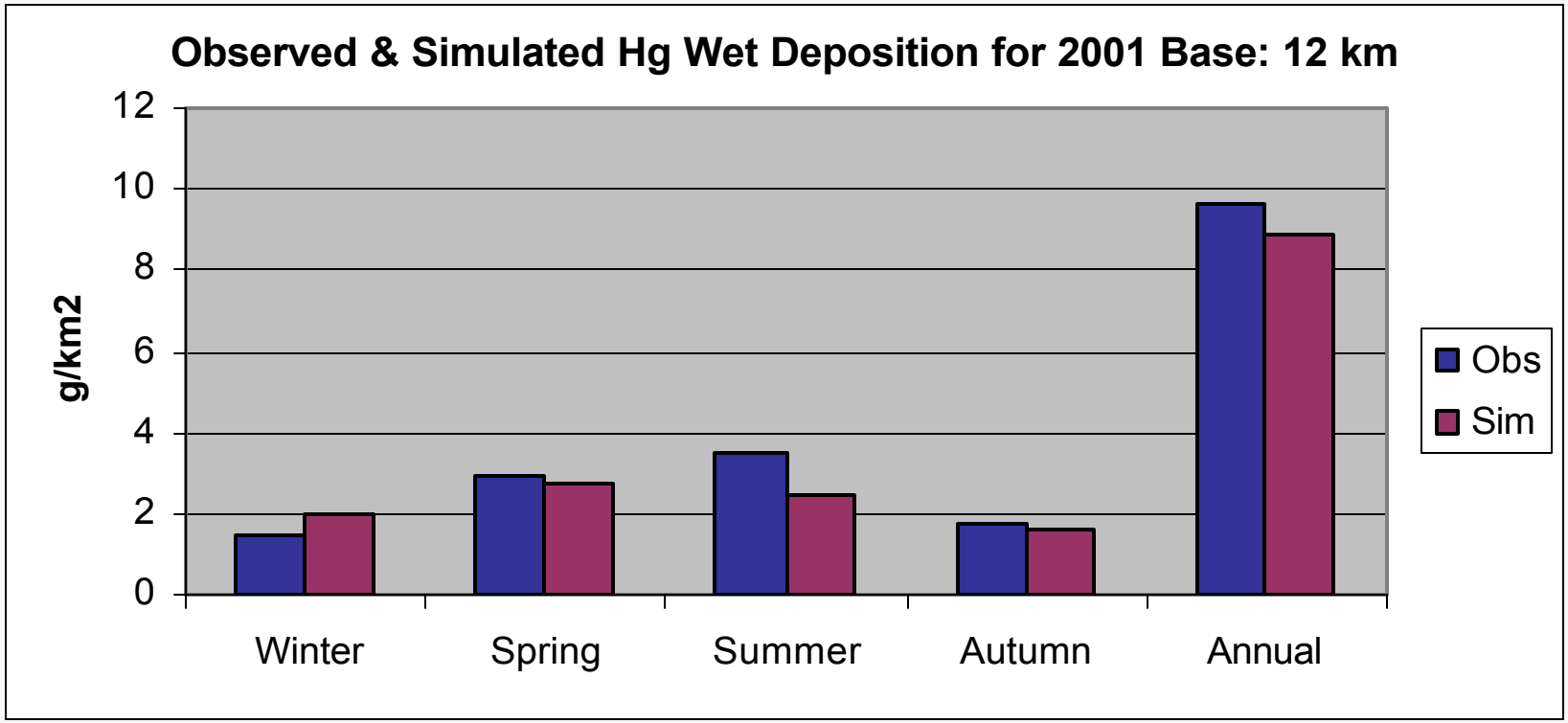
Wet Deposition

Simulated vs. Observed Wet Dep: Initial CMAQ Simulation (36 km)



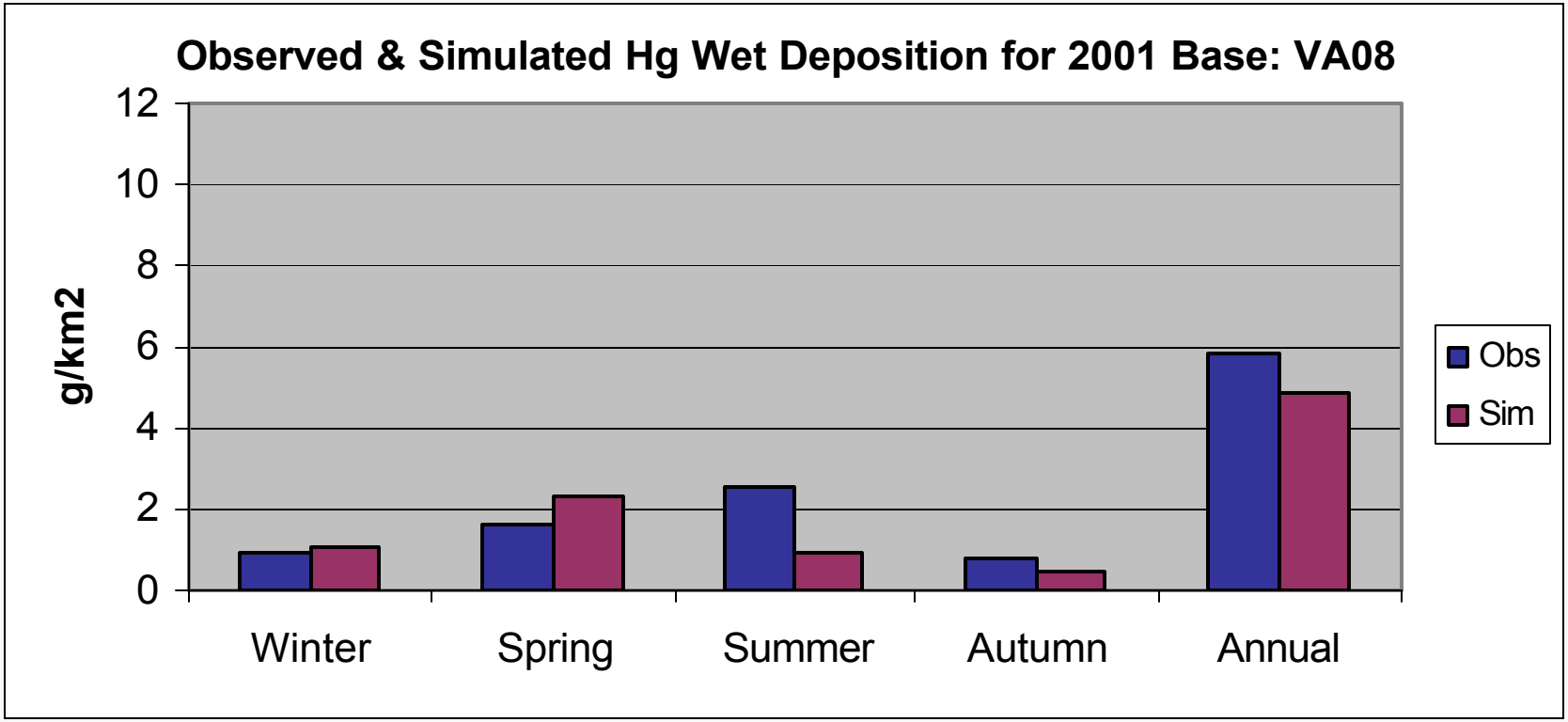
Obs based on MDN data for 43 sites

Simulated vs. Observed Wet Dep: Initial CMAQ Simulation (12 km)



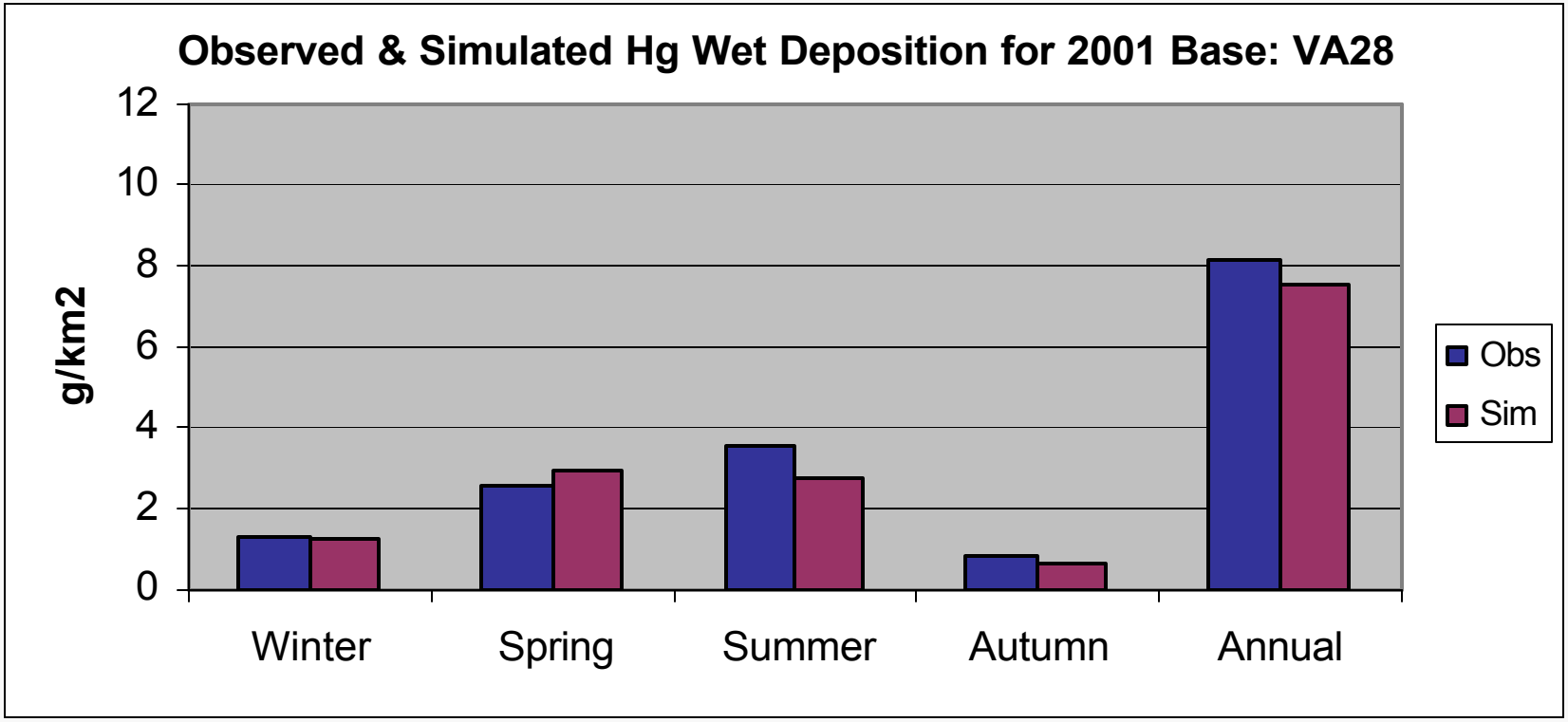
Obs based on MDN data for 12 sites

Simulated vs. Observed Wet Dep: Initial CMAQ Simulation (Culpeper)



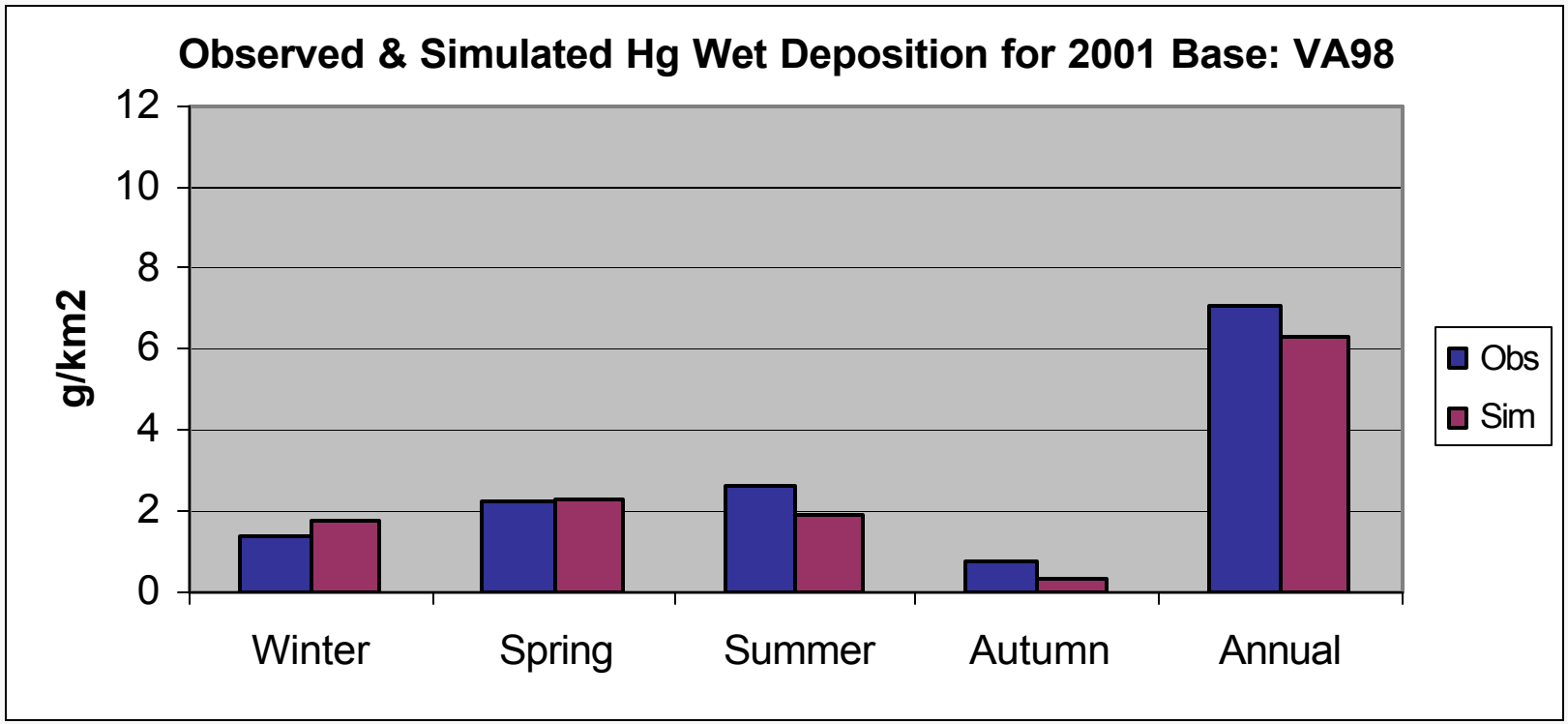
Obs based on VA estimated data

Simulated vs. Observed Wet Dep: Initial Simulation (Shenandoah)



Obs based on VA estimated data

Simulated vs. Observed Wet Dep: Initial CMAQ Simulation (Harcum)



Obs based on VA estimated data

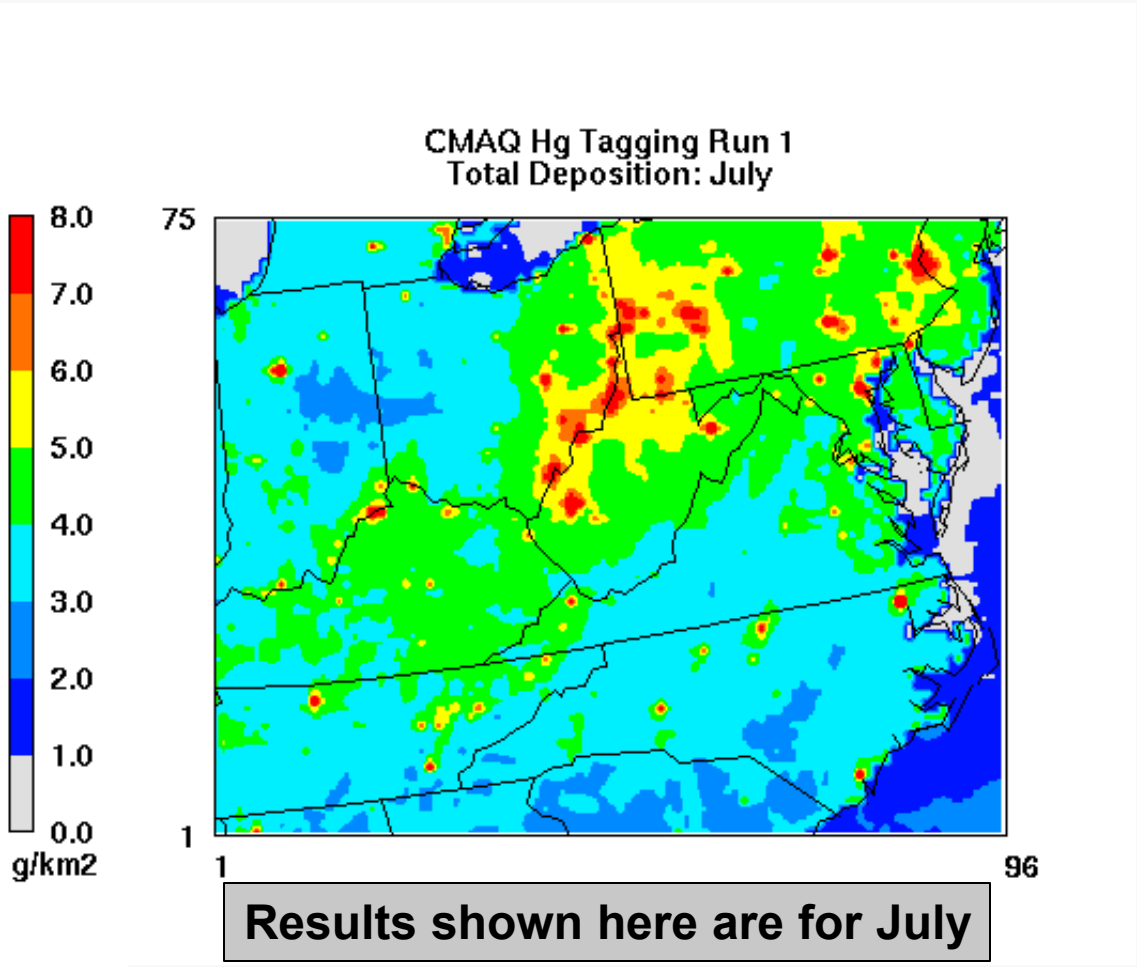
Preliminary Application of CMAQ Particle & Precursor Tagging Methodology (PPTM)

- Tags can be applied to IC/BCs, source regions, source categories & individual sources
- PPTM quantifies the contribution of tagged sources to simulated species concentrations & deposition

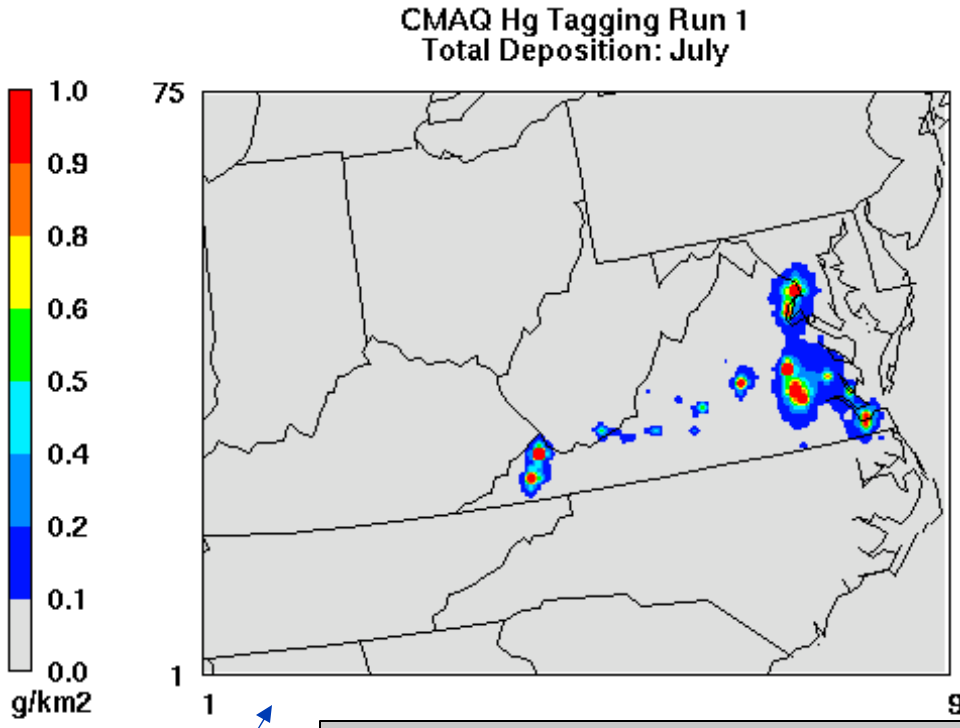
Preliminary Application of CMAQ Particle & Precursor Tagging Methodology (PPTM)

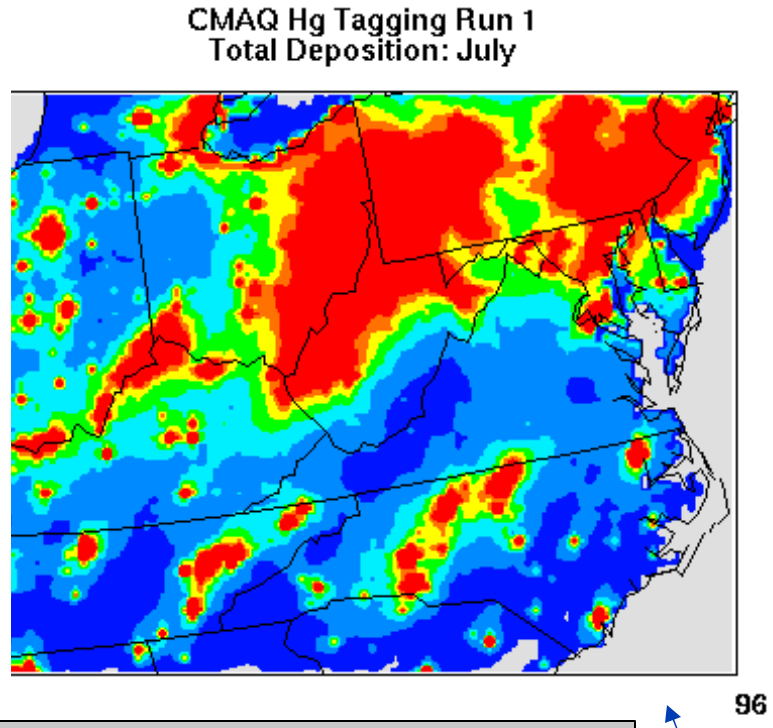
- PPTM #1
  - Tag 1: All anthropogenic Hg sources in VA
  - Tag 2: All other Hg sources in the 12-km grid
- PPTM #2
  - Tag 1: EGU sources in VA
  - Tag 2: Other EGU sources in the 12-km grid
  - Tag 3: All other Hg sources in the 12-km grid

Initial CMAQ Base Results: Total Mercury Deposition



Results for PPTM#1: Total Mercury Deposition



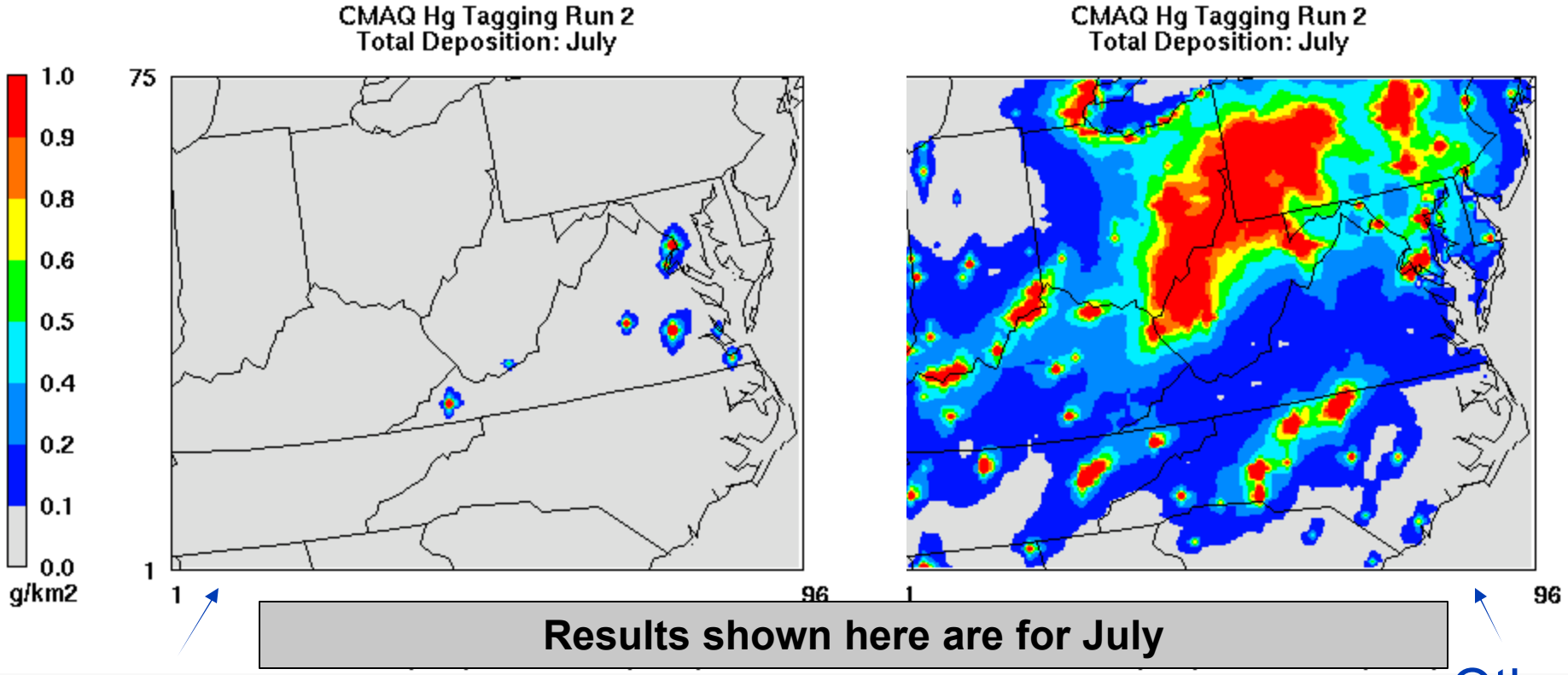


Results shown here are for July

Virginia sources

Other sources

Results for PPTM#2: Total Mercury Deposition

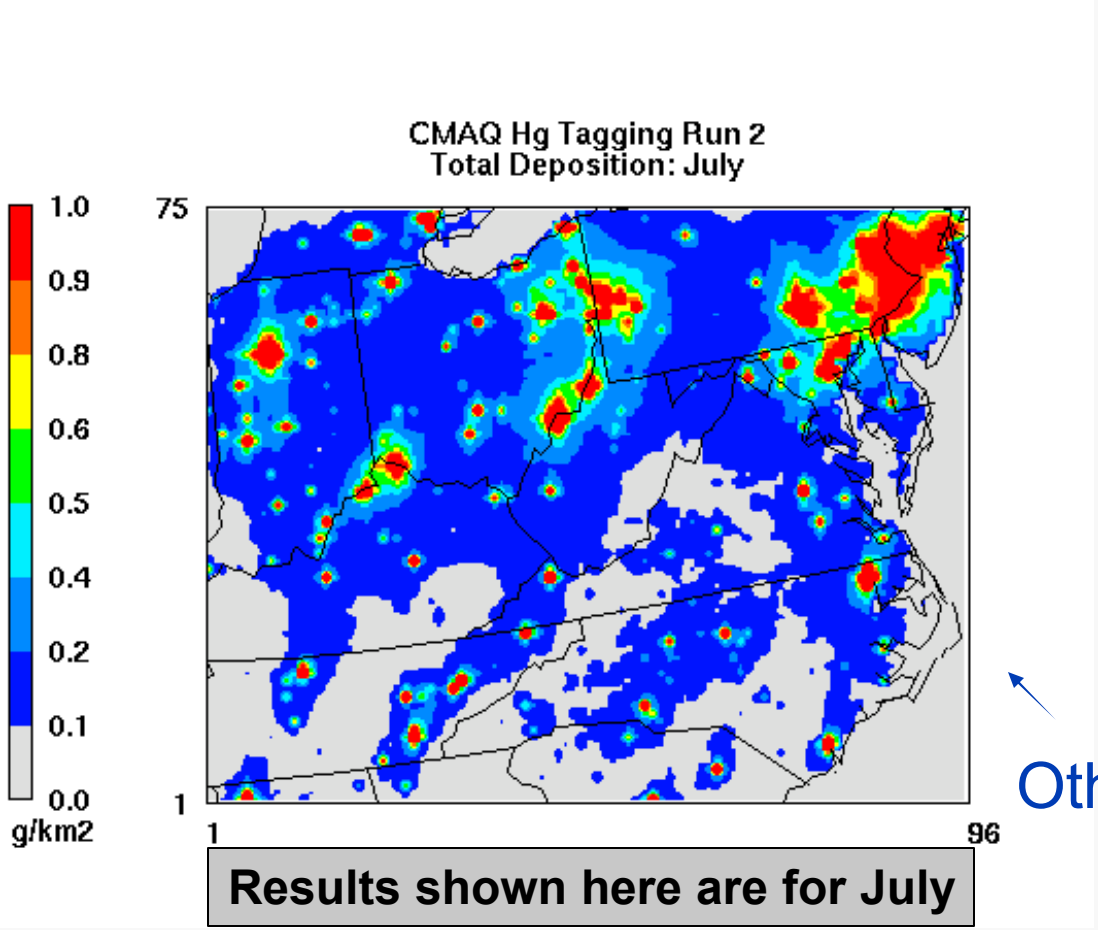


Results shown here are for July

Virginia EGUs

Other EGUs

Results for PPTM#2: Total Mercury Deposition



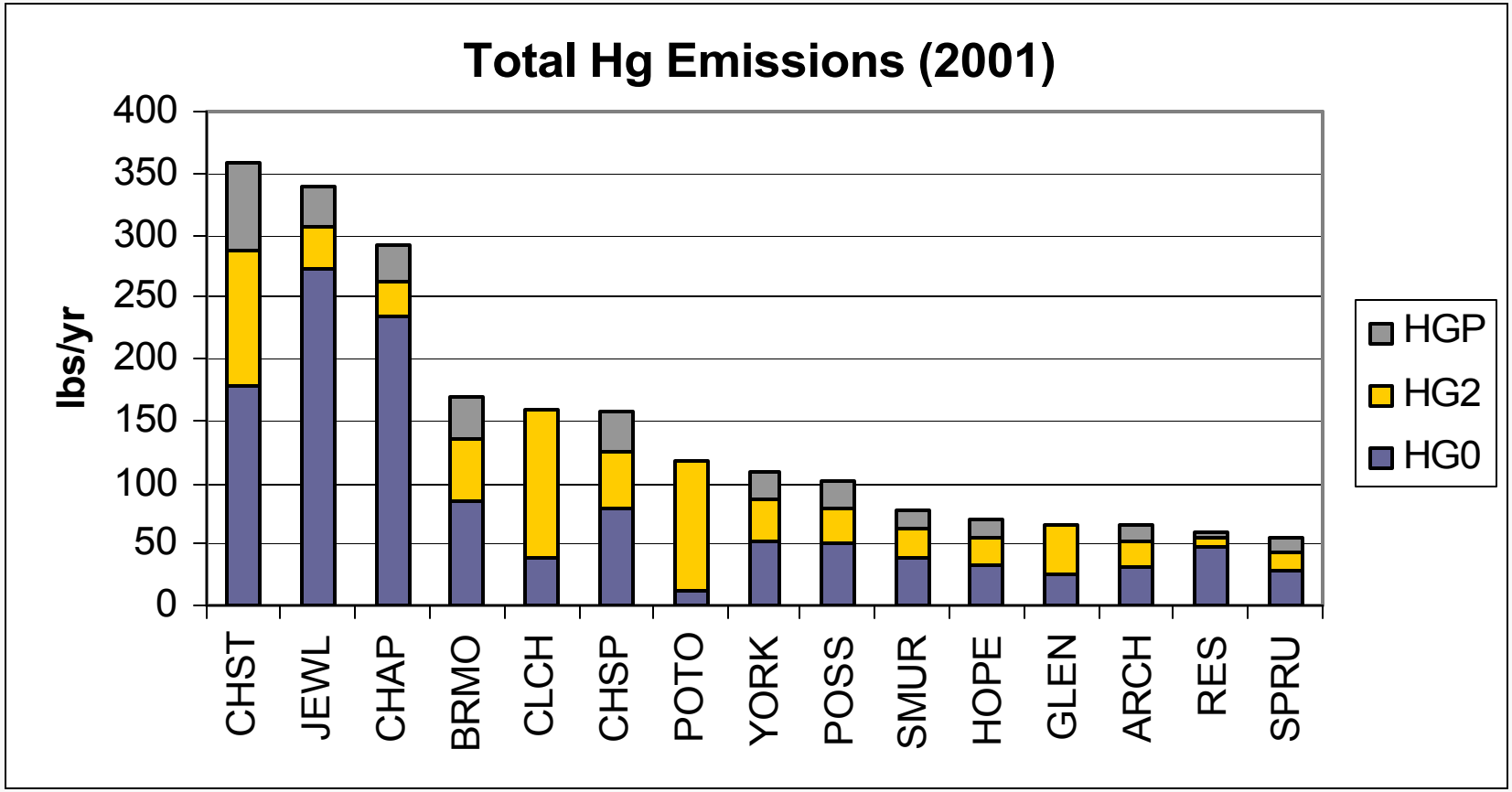
Other Hg sources

CMAQ Animation

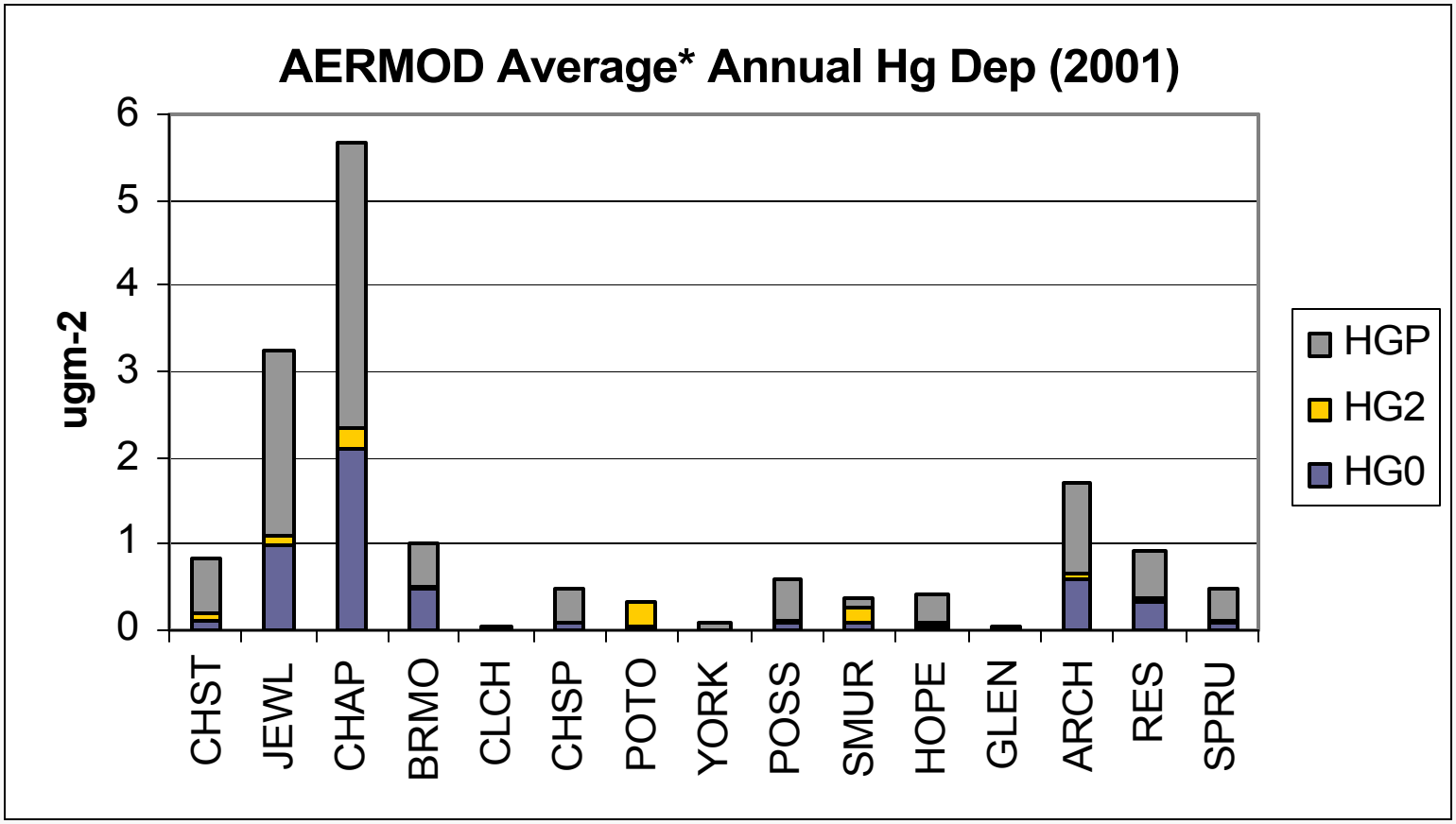
AERMOD Mercury Deposition Modeling (Base Year Application)

- Focused on top 15 emitters/facilities
- Examined sensitivity of results to input parameters/options
- May use AERMOD results to identify individual sources for tagging (CMAQ PPTM)

Base-Year Hg Emissions for Top 15 Facilities in VA

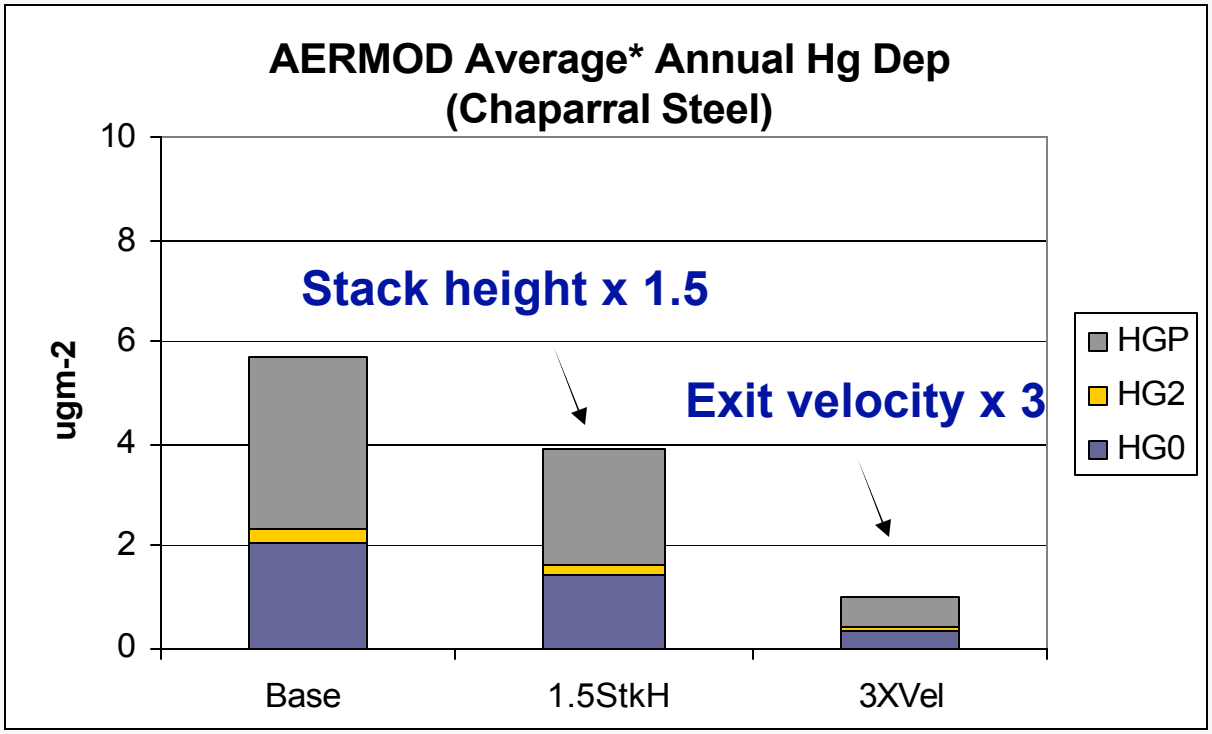


Summary AERMOD Results for 15 Highest Emission Facilities in VA



*Average over 3 km sq. area surrounding facility

Sensitivity of AERMOD Results to Stack Parameters



⇒ AERMOD results very sensitive to changes in stack parameters

⇒ Stack parameters account for comparatively higher deposition for Chaparral Steel

Summary of Findings to Date from Mercury Deposition Modeling

- CMAQ produces reasonable deposition amounts (compared to observed wet deposition data)
- As expected AERMOD-derived deposition values are greater than CMAQ values (& are sensitive to stack parameters)
- Wet & dry deposition have distinctly different spatial & temporal patterns & vary with meteorology

Summary of Findings to Date from Mercury Deposition Modeling

- CMAQ/PPTM can be used to track the fate of mercury emissions from selected sources & quantify their contribution to CMAQ-derived concentration & deposition estimates
- Preliminary PPTM results indicate that
  - Both local & regional sources contribute to Hg deposition in VA
  - Transport from outside of the 12-km domain is an important contributor to mercury deposition in VA

Ongoing/Planned Base-Year Mercury PPTM (Tagging) Runs

- Use mercury “tagging” capabilities of CMAQ to quantify contributions from:
  - Virginia sources
  - Neighboring states
  - All other states
  - Canada/Mexico
  - Global
  - EGUs & non-EGUs

Planned Future-Year Emissions Inventory Preparation & Modeling

- Prepare future-year modeling inventories for 2010, 2015 & 2018
- Conduct future-year modeling with CMAQ & AERMOD to assess
  - Expected changes in mercury deposition, including the effects of future national controls (CAIR, CAMR, CAVR)
  - Potential need for additional state controls
- Study to be completed by March 2008